(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 October 2004 (07.10.2004)

PCT

(10) International Publication Number
WO 2004/086288 A2

(51) International Patent Classification[7]: G06K

(21) International Application Number: PCT/US2004/008773

(22) International Filing Date: 22 March 2004 (22.03.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/396,064 24 March 2003 (24.03.2003) US
10/729,696 5 December 2003 (05.12.2003) US

(71) Applicant (*for all designated States except US*): **NTAG INTERACTIVE, LLC** [US/US]; 52 Riverside Drive #14A, New York, NY 10024 (US).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **BOROVOY, Richard, D.** [US/US]; 221 Columbus Avenue #404, Boston, MA 02116 (US). **EBERSTADT, George, A.** [US/US]; 52 Riverside Drive #14A, New York, NY 10024 (US).

(74) Agent: **BOROVOY, Roger, S.**; Fish & Richardson P.C., 500 Arguello Street, Suite 500, Redwood City, CA 94063-1526 (US).

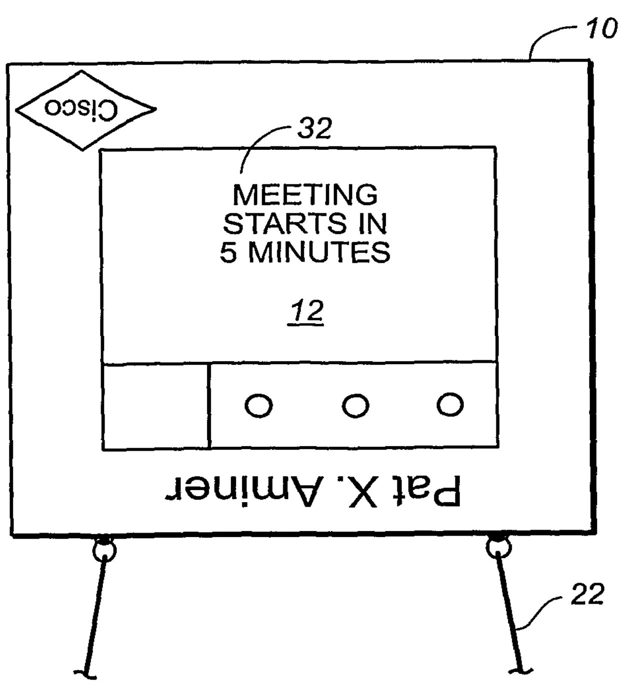
(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

[Continued on next page]

(54) **Title:** APPARATUS AND METHOD FOR ENHANCING FACE-TO-FACE COMMUNICATION



(57) **Abstract:** A wearable electronic tag for displaying graphics and text images and for communicating with other similar tags. Each tag includes a visible, graphical display adapted to be worn by a user. The tag also includes a short range, substantially unidirectional electronic communication channel, such as an infrared transmitter-receiver, located on the display unit so that, when the display unit is worn, the interface faces in a direction of the desired communication with another person who also is wearing a similar tag. This arrangement makes possible automatic data exchange and comparison of the interchanged data and display of the results of the comparison on the tags worn by the two wearers. The tags also have a longer range wireless communication system to receive and transmit data.

WO 2004/086288 A2

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

APPARATUS AND METHOD FOR ENHANCING FACE-TO-FACE COMMUNICATION

CROSS-REFERENCE

This application is a continuation-in-part of application no. 10/396,064, filed March 24, 2003.

BACKGROUND

This invention relates to a method and apparatus for facilitating face-to-face communication. More specifically, the invention relates to a wearable display that has communication capability, allowing the wearers' displays to communicate with each other, either with or without any action by the wearer.

Over the past several years, technology has been developed at the Media Laboratory of the Massachusetts Institute of Technology to facilitate face-to-face communication. One of the inventors of this invention has done pioneering work in the development of "intelligent badges" worn by meeting participants to take the place of paper badges. Early incarnations of this technology used badges that contained multiple LEDs that communicated with each other. The signals transmitted between the badges denoted the answers to preprogrammed, multiple-choice questions. By watching the number of LEDs that lighted up when two people wearing these badges came close to each other, you could ascertain the number of multiple-choice questions that the two people answered with the same choice. For example, if there were five LEDs on the badge, and three lighted up when the two people approached each other, they both knew that they had answered three questions with the same choice.

This technology was later expanded by included coded ideas. Data could be entered into the badges expressing an idea. An idea was displayed in text on a wearer's badge. When two wearers approached each other, if one agreed with the idea of the other (he could read the idea on the other person's badge), he could press a button on his own badge and that idea would be "accepted." Since the acceptance was memorized, data could be gathered at the meeting about which ideas received wider and which received lesser levels of acceptance among the participants.

SUMMARY

Briefly, the apparatus of this invention relates to a wearable electronic display unit for displaying graphics and text images and for communicating with other similar wearable displays. The display unit, for the purposes of easy reference and not by way of limitation, will hereinafter be referred to as a "tag." Each tag includes a visible, graphical display adapted to be worn by a user and capable of displaying text and graphical images. The tag may be worn around the wearer's neck, for example, on a lanyard, or clipped to the person's belt or clothes. A preferred embodiment of the tag is about four inches square and less than an inch deep, except for the battery. The battery may add an extra quarter of an inch to the depth. The tag weighs about 6 ounces.

The tag also includes a short range, substantially unidirectional electronic communication channel, such as an infrared transmitter-receiver, as is well known in the art, having a data transmitting and receiving interface incorporated into the display unit. This interface is located on the display unit so that, when the display unit is worn by its wearer, the interface and the display face in a direction of the desired substantially unidirectional communication, so as to make electronic communication between tags. In this configuration, the two tags can exchange data, and each tag wearer can view the display of the tag worn by the other tag wearer. This arrangement makes possible data exchange between respective tags worn by two wearers through the interfaces on the respective tags.

In a preferred embodiment of the invention, the tag may have two electronic means of communication, one short range, such as infrared, and one longer range, such as radio frequency identification communication ("RFID"), well known in the art and long been used to electronically pay tolls at a toll gate. RFID is a medium range communication channel, for example, less than 20 feet. Alternatively, the longer range communication could be WiFi (IEEE 802.11 and its successors), or other radio communication systems. In one embodiment of the invention, the tags can include a GPS receiver so that the precise location of the wearer can be ascertained. Any or all of these communication, location or identification systems can be advantageously combined for the purposes of this invention.

In addition to the tags being capable of communicating with each other, they also may communicate with other things, such as a signboard, permitting the signboard to personalize its message based upon information transmitted to it by a tag. An additional desirable feature of a tag of the invention is a timer so that the actual, or relative time of various communications or actions by the wearer (such as entering a room or encountering another tag wearer) can be kept track of and used for various of the methods of this invention.

The tags each have a microprocessor and a memory. Data can be entered into the memory in several ways. For example, the tag will have at least a minimum number of keys or buttons, such as "scroll up," "scroll down," and "select." The tags may also have a scroll wheel, such as a clickable scroll where (where a choice is indicated by depressing the scroll wheel), just as PDAs do, to scroll up and down through menus or text. If desired, a complete keyboard can be included. This facilitates manual data entry. In addition, data can be transmitted to the tags from an RFID reader or any other radio system. When a wearer passes such a reader, data can be placed into the tag. Data can also be "broadcast," for example to an entire room, using RFID transmission and downloading the data into all tags in range, or by using appropriate coding, just to selected tags. Finally, the tags may have a wired port, such as a serial port, where data can be downloaded from a computer, such as a personal computer ("PC").

The display of the tag, such as an LCD display, may be backlit, and may include a backlight turn-off timer to save battery power. The tag may also include additional visible indicia, such as a light or a flashing light. Alternatively, or in addition, the tag may emit a sound or a beep to signal the wearer. Preferably, the light is located in a place on the tag where the wearer can normally see it.

In addition, the display may be adapted to be viewed both by the wearer in one mode, and by a person who is nearby in another mode. For example, the tag can hang around the neck of the wearer, and the text will be viewable by a passersby. However, when the wearer lifts the tag up to read it, the text inverts so that it easily may be viewed by the wearer. Furthermore, when the wearer is reading the tag at close range, the text may become smaller to allow more text on the display. However, when the tag is being viewed by another person, the text may enlarge so that it may be read

from farther away. In order to change modes automatically, the tag includes a sensor that detects whether the tag is oriented in one vertical direction, or in the opposite vertical direction. Such tilt sensors are well known in the art.

The invention also includes a method of communicating face-to-face using a tag of the invention. This method of communication takes place by passing a first packet of information electronically from the tag of a first wearer to the tag of a second wearer, the information including personal information about the first wearer. Then text information is displayed on the tag of the second wearer that is based upon a comparison between the first packet of information passed by the first wearer, and a second packet of information contained within the tag of the second wearer. The second packet of information includes personal information about the second wearer. Then text information is displayed on the tag of the second wearer and is visible to the first wearer. The displayed text information includes information that resulted from the comparison of the two packets of information.

Then one or both of the two people can take various actions based upon what they have seen on the other person's tag, all as will be described in the complete description of the preferred embodiment and drawings, which follow.

DESCRIPTION OF DRAWINGS

Fig. 1 is a front view of the display unit of this invention;

Fig. 2 is a top view of the display unit of the invention;

Fig. 3 is a side view of the display unit of this invention; and

Fig. 4 shows the display unit of the invention in the opposite orientation.

DETAILED DESCRIPTION

The tag of this invention is shown in Figs. 1-4. Referring to the figures, tag 10 has its electronics all inside the module. It is manufactured in a similar manner to a personal digital assistant of the type marketed by Palm and many other companies. The unit includes a microprocessor, memory, such as flash memory, or other types of faster memory, all as well known in the art, and depending upon the application and various interface electronics and communication devices, including RFID and infrared (these are inside the unit and are not shown in the drawings). These are interconnected, as is know in the art, on a printed circuit board.

The unit is adapted to hang around the wearer's neck using lanyard 22, although it can have a clip or other attachment mechanism on the back (not shown) to attach it to the wearer's clothing. The lanyard is preferably an adjustable length lanyard so that the shorter length allows the tag to hang high on the wearers chest in the tag mode, when it is to be read by someone else, but uses the longer length needed when the tag is to be raised for reading by the wearer. When the tag is to be read by someone other than the wearer, it is in the "tag mode."

It is important for this invention that the display 12 on tag 10 and the communication interface 20 both face outwardly so that communication is possible with another tag wearer standing face-to-face with the first wearer. In that way, each wearer can see display 12 of the other wearer, and the communication interface 20 is facing a similar communication interface on the tag 10 of the other wearer.

If desired, the tag may have a sticker, preferably a removable sticker, affixed to the front. That sticker may have printed on it the wearer's name 24 and the wearer's affiliation shown in logo 26. Alternatively, the wearer's affiliation can be printed below the wearer's name on the top, and the logo 26 can be the logo of the host of the conference, for example. This sticker is important in case a tag is mislaid. These stickers are removable and can be personalized, as these tags are used over and over again for different wearers.

When two people wearing these tags 10 are standing face-to-face, their respective communications interfaces 20, which can be, for example, an infrared transmitter-receiver, communicate with each other. In a preferred embodiment, the IR transmitter-receiver is tuned to begin information exchanges at a range of about three feet. Infrared transmitter-receivers are well known in the art. One example, as shown in Appendix A, is the IrDA Data Compliant 115.2 kb/s 3V to 5V Infrared Transceiver Model Nos. HSDL-3610#007 and HSDL-3610#008 made by Agilent Technologies. In that way, data contained in the memory of each unit can be passed to the other unit. A receiving unit can process a received packet of information, combine it with a packet of information contained within the receiving unit, and then display the results of that combination on the receiving unit. Alternatively, the tags may communicate with each other by other means, such as radio, for example, using the Bluetooth standard. Many examples of this will be explained below.

Not shown in the drawings, but contained in tag 10, is an RFID communication system, as is well known in the art. RFID is a backscatter system. Base stations called "readers" generate a strong RF signal. The tags remodulate the signal and use the energy of the transmitted signal to send back information to the reader. This minimizes the power requirements for the tags. Almost no energy from the tag is required for the remodulation and retransmission. The tags of the invention can be powered for five days with four AAA batteries. If desired, rechargeable batteries also can be used.

RFID is a very robust communication, medium range communication system, able to withstand many types of interference that would harm other types of radio transmissions. Such interference is generated by cell phones, wireless microphones, walkie-talkies, remote landline phones, and/or wireless networks. RFID systems allow large numbers of users to roam about large areas without any reprogramming required.

Within the tag 10 is an antenna and encoding system (not shown), as are well known in the art, so that information is transmitted from an RIFD reader, within reading proximity of the tag, to the tag's memory. Similarly, data from the memory of a tag passing within range of a reader will be transmitted to the reader, for example, for further transfer to a computer for collation with data received from other tags. An example of such an RFID system is described in an article entitled "WHITE PAPER – Multiband, Low-Cost EPC Tag Reader," by Matthew Reynolds, et al., published on June 1, 2002, by the Auto-ID Center, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Buildling 3-449, Cambridge, MA 02139-4307. See Appendix B. Other RFID systems, including readers and transponders of the type that are incorporated in the tags of this invention are described in U.S. Patent Nos. 5,055,659, 4,739,328, 4,782,345, 4,786,907, 4,816,839, 4,835,377, and 4,853,705 – all of which are incorporated by reference.

Of course other radio communication systems can be employed instead of or in addition to RFID. For example, the tag radio may act as a relay station, relaying messages from one tag to another, or from a tag to a central transmitter-receiver. The base transmitter-receivers are located around the meeting venue or convention hall to provide the relay function. In this embodiment, an individual tag communicates

primarily with the base units. However, tag-to-tag radio communication for data exchange can still be employed using the same relay technique, and can be used for the detection of the proximity of one tag to another.

There are a variety of ways to enter and retrieve data into and from a tag. In most conferences, attendees preregister, usually on the worldwide web. This data is collected by the conference planners and can be collated and downloaded into each participant's tag. For this purpose, a tag may have a port, such as a serial port, through which data may be downloaded. This interface is well known, and is used, for example, to synchronize a PDA to a PC. When the conference is over, data may be uploaded from the tag to a computer using the same port.

In addition, data may be entered or retrieved from a tag using an RFID reader. When a tag passes in range of such a reader, the reader, as is well known in the art, can download or upload data to or from a tag.

Of course the tag itself can be used for obtaining and transmitting data. The infrared channel built into the tag transmits data to other tags, receives data from other tags, and can be used also to transmit data to a PC, either directly to an infrared transmitter/receiver on the PC (as commonly come with laptop computers) or using an extra tag intervening between the tag to be read or provided with data, and the PC. In this application, the extra tag can, for example, be attached to the PC through its serial port. This tag-to-tag method using RF has an advantage over using RFID for loading or unloading large amounts of data, as IR normally has wider bandwidth than RFID.

And finally, a wearer can enter data into his own tag by using the buttons 14, 16, and 18. For example, button 14 can be used as a scroll down button, button 16 as a scroll up button and button 18 as a select button. In that manner, the user can select choices from lists downloaded earlier into a tag, or answer multiple-choice questions. Alternatively, if desired, voice recognition can be installed in a tag so the user can enter data by speaking into the tag. The sensitivity of microphone that receives the voice commands may be changed, depending on whether the tag is in the "menu mode" (where only the wearer's voice is to be heard), or when the device is in the "tag mode" where the voice would come from a few feet away.

There is a growing use of the World Wide Web to create multi-user social network databases. For example, a website such as "Friendster" allows users to enter

their profiles into the network, as well as entering the names of all the people they know. Then a user of Friendster can look, for example, for a particular person that she would like to meet, such as the movie star Tom Hanks. If someone that she has listed as a friend has listed Tom Hanks as a friend, the network will pop up with that person's name. Then the user need only call or email her friend that knows Tom Hanks, and ask for an introduction. If none of her friends happen to know Mr. Hanks, the network will search a level deeper to see if any friends of those she listed as her friends happen to know (have listed) Mr. Hanks as a friend. If so, the website will provide the name of both the friend (the first order contact) and the friend of the friend (the second order contact) to the user. Through those two people, perhaps an introduction can be arranged.

The tag of the invention can be very useful in connection with such a social network database. The tags keep track of people with whom a wearer has come in contact, as described above. This information can then be downloaded into the social network database. Therefore a person's social network will contain not only historical relationship data that the person has entered into the network, but real time data about people a wearer has recently met face-to-face, that can be uploaded, according to the invention, from the tag to the social network database using the techniques described herein.

Additionally, social network data can be downloaded into the tags. Then, when a wearer meets someone face-to-face who also has his social network in the tag, the two people can immediately find out to what extent their social networks overlap. Each tag can display a list of any or all people that the two people who are meeting know in common. This is similar to the real world social game people play when they meet new people. They spend a good part of their initial conversation time trying to find out who they may know in common. Using the tags and the social network, the game can be speeded up immensely, enabling the conversation to be focused on the people the two wearers know in common, rather than spending the time and effort first to find out who these people are. The tags perform that function in conjunction with each person's social database contained in their respective tags. This function may also be performed by using the tag's radio to query the social network database running on a remote server in real time, rather than having the data stored on the tags themselves.

Additionally, if a person wearing a tag wants to meet someone who is attending the meeting, the social network may be employed so that, if a person meets someone who also knows the person who is being sought (and perhaps may have spotted that person), it becomes easier for a person to find that person. The tags can draw on the social network data to suggest introductions.

If a person going to a meeting wants to do so, she can access an online tool in advance and use her social network, together with a list of meeting attendees, to find out what friends of her friends may be present at the meeting. This information can be downloaded into her tag she is going to wear. Alternatively, the social network database can be queried in real time during the meeting, using either radio or the RFID readers described herein. The tags can then be used at the meeting, as described herein, to locate those friends of her friends.

After an event, or even during the event, the tag wearer can download from his tag the contacts made at the event into his social network as described herein.

Kiosks located at central or entrance points at an event can be used to download or upload data into and out of the tags. The kiosk can have a PC with an attached tag, so the wearer of a tag can approach the attached tag (or "dip" his tag into a bucket containing the attached tag) and receive or transmit data. Alternatively, the kiosk can have an RFID reader and the tag can get or send data that way. There are also a number of beaming systems becoming available which provide self-contained beaming sources connected to a central server, either wired or wireless. These may be used to get data into the tag. Another method of getting data into a tag is from a PDA, beamed directly to the tag. The PDA can get data when it is synched to a PC, or otherwise. The user enters data onto his/her palm and from there beams it in to his/her tag.

Another feature of the invention is shown in Fig. 3. Light 28, on top of the unit, can light up when the tag wants to get the attention of its wearer. Alternatively, a buzzer or beeper can be used (not shown), either audible or vibrating, for the same purpose. If desired, the lanyard which holds the tag around the wearer's neck can be the source of the vibration to alert the wearer. Applications of these features will be described below.

An important feature of the invention is illustrated in Fig. 4. In that figure, the display unit is turned upside down. This is done because the wearer would like to read a message being displayed on her own tag. This mode is called the "menu mode." In Fig. 4, that message 32 is "Meeting starts in 5 minutes." It is seen in Fig. 4 that in spite of the fact that the display unit is upside down (as it would be when raised up by the user while retaining lanyard 22 around her neck), but the text message is right side up. This is because the display unit 10 includes an orientation sensor (not shown) that senses whether the tag is hanging top up, as it is normally worn, or has been inverted, as shown in Fig. 4.

A commercial tilt sensor may be used, such as a GP1S36 tilt sensor from Sharp Electronics in Japan. This sensor is described in the Sharp specification sheet entitled "GP1S36 Photointerrupter for Detecting Tilt Direction." See Appendix C. The emitted signal from the sensor indicating that the tag has been inverted causes the text displayed on the graphical display 12 to become inverted so that it can more easily be read by the wearer. In addition, if desired, the text also can be switched to a smaller text so that longer messages may be displayed to the wearer. Then, when the tag is put back into its normal, hanging position, called the "tag mode," the sensor senses this orientation, and the text mode is re-inverted and, if desired, made larger so it can more easily be viewed by another person standing opposite the wearer. Alternatively, if desired, a user input (from a button, for example) may be used to switch modes.

There are various ways to read the tag in the mode to be read by the wearer. This mode is called the "menu mode." One way is to have a menu set-up, with entries in the menu being ranked in some way. These entries may be placed there before you received your tag at the beginning of the conference, or later by an RFID reader or other wireless communication medium. For example, the item you read last in a menu can remain on the top of the list until you delete that item. Alternatively, the menu can always go back to the top of the list. Typically, the most important thing that you may want to view resides on the top of the menu list. For example, it can be an ordered list of the people you have engaged with at the conference (and thus had their names recorded on your tag). Or the top item can be selected in context sensitive manner, if this selection has been programmed into the tag.

If you are in a talking mode (meeting people, but not passing by RFID readers), one class of items, such as a list of whom you have talked to, can be at the top of your list. On the other hand, if you are passing by an RFID reader, the top item on your list can change to a conference agenda if, for example, you are going to a meeting when you pass by that reader. If the reader is located at an entrance to the exhibitors' booths, the top item in your ordered list can be a list of the booths and their locations. Artificial intelligence can be used to decide what each person should have on the top of his or her own list. The timer can be used in making these decisions (keeping track, for example, of how long it has been since you have interfaced with another person, or how long it has been since you have passed a particular RFID reader).

Another embodiment of the invention is to combine a tag with a PDA. For example, when using the combination unit as a PDA, the IR interface faces out the end of the unit (for example, the part shown in Fig. 3). When using the device as a tag, the IR device faces out the front of the unit as shown in Fig. 1 (element 20). Alternatively, the device can have two IR transmitter-receivers, one on the top and one on the front, and the transmission can be switched from one to the other by using a switch, or by using the orientation sensor described above. Alternatively, mirroring devices or other light switches can be used to switch the IR beam from outputting from one location on the tag to another location.

In addition, the tags can have other mechanisms for communication, such as WiFi receivers, compliant with IEEE 802.11 and any successor standards. These can be used for communication as well. This will allow easy communication to a central website or to a central host computer at the conference. Any other form of radio communication known in the art can also be employed in the tags, provided that interference problems can be overcome.

Tags can have additional information gathering devices beyond the IR and RFID communication media. For example, a tag can contain a GPS locating device, allowing the tag to "know" where each person wearing a tag is presently located. A location detection system that works through triangulation may be used in addition to GPS where GPS does not provide good enough in-building coverage. GPS works better outside than it does inside a building. If that location information is sent

through RIFD readers to a central location, and there are enough RFID readers, it becomes easy to locate someone at any time. If you are told that you should find another person, you can enter that person's name in your tag, walk by an RFID reader and get data as to that person's whereabouts at the conference. Similarly, your tag will pass your location to an RFID reader when you pass it. Alternatively, if the tags have radio transmitting capability, your location can be continually broadcast to a central computer. A tag can then interrogate the central computer in the same way and ascertain the location of any other tag wearer. When you have been told that you have something in common with another person at the conference, as will be described later, this will assist you in finding that person. Various rules may be applied to determine who gets access to a person's location information. For example, as a tag wearer, I can make a choice and enter that choice into my tag, indicating (1) that anyone can have my location information; or (2) only people I have "met" (engaged with for a predetermined amount of time) may have it; or (3) only people I have specifically named individually or as a group, for example, only some or all of the event staff.

The tags of the invention can also incorporate communication of the type used in cell phones. In this way, information can be downloaded or uploaded to or from a tag using the telephone system. The tag can also use radio or satellite communication systems such as now commercially used by the "Blackberry" type of hand-held email devices. And, of course, if the tags have both PDA and cell phone capabilities, a wide variety of modes of communication with a tag become possible. SMS, another communication system known in the art, can also be incorporated into the tags.

There are many new methods of this invention that make use of tags described above. These applications are made possible because the tags can combine information. The information to be combined can come from (1) the memory within the wearer's tag; (2) communications transmitted to the tag from an RFID reader, or broadcast wirelessly to all tags or to selected tags; (3) the information in the memory of another tag in IR communication with your tag; or (4) information entered into a tag using buttons 14, 16, and 18. These buttons are merely an example. The tags can have a full keyboard or more buttons, if desired. The three buttons are adapted for short inputs, such as selecting from a menu, scrolling up or down a list, or indicating an action, such as agreement (or disagreement) with a message being displayed on the

wearer's tag or on another person's tag standing opposite the wearer. Examples of these new methods of the invention are set forth below.

One use of the tag of the invention is to keep track of people that a wearer meets at a conference. The tag has a built in timer that can be used to time how long two tags are in contact with each other, or to time any other elapsed time or real time. Messages can therefore bear a time code. Elapsed time after a tag wearer has passed a reader can be retained. "Face time" – the time spent talking or interacting with another tag wearer can be measured. The tag may be programmed to require a preset amount of face time during any engagement before it records the name or affiliation of the individual with whom a tag wearer is communicating. This minimum time can be set, for example, to one minute. The tag will then remember each person the wearer has communicated with for at least one minute. That avoids storing data from very brief "hello" types of encounters, or unintentional encounters, such as people you pass in the halls. For each person you spend at least a minute with, his or her name (and any other data, such as affiliation, as programmed into the tag) is passed from his or her tag, to your tag, and vice versa, and kept, for example, as a list in the memory of the respective tags.

When you meet someone, your tag can compare the names of people you have met at the conference with the names of people she has met. If desired, one or both tags can then produce a list of those people the two tag wearers have met in common. If names are not necessary, the tags can display the number of people whom the two wearers have met in common, thus demonstrating whether the two wearers have been mingling in the same circles, or the extent of the overlap between the people one person met compared to another. In addition, one or both tags can display the name of the person that both wearers most recently met in common. The built-in timer can associate the time of each face-to-face contact and produce an ordered list.

A tag can keep track of second order meetings. For example, a tag can display the name of a third person that has met a person you have met. Alternatively, when the wearers come face to face, one wearer's tag can display the names of all people that the wearer has met who have also met that same third person, perhaps a person you are looking for. Either tag can also display the meeting times, or display a list of names that are ordered in order of the times when each of the listed people have met

that third person. Each tag also can keep track each time a wearer passes by an RFID reader. That information can also be transmitted to other tags with which the tag communicates, thereby, at least to some extent, enabling someone to locate someone else, as will be discussed further.

The matching can be broadened to include interests, background or other things that two or more people at a conference may have in common. For example, if the hobbies of each conference attendant are programmed into their respective tags, when you approach someone and pass onto her the fact that your hobby is model trains, her badge can indicate if that also is one of her hobbies, or if she has previously engaged (according to the rules of engagement preset within the tag) with another person whose tag also indicated that his hobby was model trains. Then the tag of the person you are talking to can, if desired, list the name of that other person and the time that the person with whom you are presently engaged met the third person with the model train hobby (and, if desired, also the elapsed time since that person met the third person with the train hobby).

The tags not only can match any item on the profile of the person with whom you are presently engaged, but also of people that that person has met. If you meet someone with nothing in common with you, her tag can be programmed to display a message: "We have little in common, but you should talk to Sally." And the message can further state: "I talked to Sally 4 minutes ago." Then you would likely ask this person where she was four minutes ago, so you can go there in search of Sally. If the tags have GPS capability, the tags will also be able to display the last known location in the room of the person who you are seeking that had a matching personal characteristic. Even without GPS, tags can contain information that tells when a person last passed an RFID reader, providing some hint as to where that person may be when you are looking for him.

Tags can make calculations about people based on the number of face-to-face interactions they have. For example, a tag can calculate and display whether you are a mingler or a social dud based upon how many people you have engaged with.

Most information using the tags of the invention is conveyed by looking at someone else's tag, not your own. This is different from prior art PDAs, for example, where you primarily will get information by looking at your own PDA, not another

person's PDA. However, you can also look at your own tag, for example, if conference information is being broadcast to all the tags.

It is important that the tags of the invention are worn so they can electronically communicate with other tags without user intervention. This is different from a PDA, where communication only takes place deliberately. With a PDA, the user takes the unit out of his pocket and aims it at another person's PDA to transmit information. There is no mode with a PDA whereby it always is in a mode to transmit to any other PDA in range. Laptop computers often automatically set up a communication path with another computer in range, but no actual communication takes place without user intervention. The fact that the tag of this invention hangs on your neck, or is otherwise worn in a manner that is always on and ready to communicate with another tag, insures at least some communication without user intervention.

The extent of unsolicited communication between tags can be user-designed. For example, when two tags come face to face, they may automatically exchange names, or names and corporate associations, but not more. User intervention may be required, such as a press of a button 14, 16, or 18, to transmit additional information, such as a business card, from one tag to another.

A very important application of the tags of the invention at a conference is to get conversation going. One way to do this is to assign each person a "secret partner." When, you meet any other person, the other person's tag will say "I'm your secret partner" or, if she is not, then it might say "I met your secret partner 10 minutes ago," or "I met someone 5 minutes ago who met your secret partner 3 minutes before I met him." This leads you to ask: "Who did you talk to 5 minutes ago?" Or the person you are talking to could introduce you to the person she met 5 minutes ago.

To get these discussions going, the conference planner can give each person the name of a few people that the person is supposed to meet. When you meet one of those people, your tag can delete that name from the list. Then the next person you are to meet comes up on the tag. Either you or the conference planner can choose the order of importance of the three people you are supposed to meet. Each person you meet can display on her tag automatically (1) whether she has already met one of your assigned people; and/or (2) whether she has met someone who has met one of your people, and, if desired, who that person is.

Another method of the invention using the tags is an entrance poll. Thirty minutes before an event, for example, your tag will flash its light to signal the user that it has a message (or sound a beep, or any other method to alert the user, such as vibration of the tag). The timer on the tag can be used to "pop the question" a preset amount of time before a speech, for example. At the appointed time, the tag will flash or sound and will display a message saying that you should answer the following question: "What is the biggest danger for your company?" Then your tag displays multiple answers, such as "(1) War in the Middle East" or "(2) The fact that your CEO is overpaid." Or "(3) Competition from Microsoft." This information and questions have been downloaded to your tag when you passed an RFID reader as you entered the room, or could have been pre-stored in the tag when the tag was handed out, or entered in any of the other ways described earlier.

You answer the question by using the buttons 14 or 16 to scroll up and down the list, and button 18 to select your choice. If you have done this before you entered the room, your answer can be read by an RFID reader as you enter the room. The results from all tag wearers in the room are tabulated by a central computer, and can be made available before the speech to the CEO who is speaking, enabling the CEO to say: "It is apparent that my excessive salary represents a problem to all of you, as 74% of you selected that as our biggest problem!" She can then focus on that issue in her talk.

Moreover, before or after the talk, when you meet someone, you can compare your answers to these questions. If you both answered the same, you have something to talk about. The tags will communicate, and if so programmed, will display whether you answered the question the same or not. If you gave different answers, each tag can display the answer given by the other person with whom you are talking, telling him how you answered the question, and vice versa. This also will provide fuel for a conversation.

In addition each the tag may record the time of the meeting and the names of the two people who are talking. When you go by a reader, not only is the answer to the question, which you selected, read by the reader, but it may also read the names of everyone you talked to, either up to that point in time, or between any prescribed points in time. In that way, the meeting planner can maintain a central database of

who has met whom (provided the respective tag wearers have walked by a reader after an encounter).

Yet another application is gather information after a speech. The tag can be timed to flash and ask you what you thought of the speech. You can respond to multiple choices, for example, using a Likert scale, using the buttons on your tag, and your answer is then collected on your way out of the room (by the RFID reader).

Another important application of the tags is to establish common ground among the attendees at a meeting. For example, before you begin inter-tag communication, you can answer a question using your tag. If the meeting is in Las Vegas, the question can be: "What show in Vegas would you most like to see?" There can follow any number of multiple choices, which you scroll and pick. When two people meet, the tags can display the name of the chosen show for each person, or whether it is the same show, or both. Moreover, a tag wearer can be a broker between two other people. If the two of you did not choose the same show, the tag can display: "I didn't choose Cirque de Soleil, but I met someone two minutes ago who did choose that show." Then the other person can try to find that person by asking the person he is now talking to for the name of the person she met two minutes ago.

The same kind of exchange works for interests or hobbies. If attendees, when they register for the conference (or later after they arrive), enter into their own tag their main hobby, that can be used in the same manner described above. When you approach someone, the tag may search through all the data commonly entered in everyone's tags. Then, if a match is found, the tag of the person you are talking to can display; "Hey! We both like model trains." Or "We are both from Eau Claire, Wisconsin," or "I see you like model trains. I met someone 4 minutes ago who also likes model trains." These displays will get conversation flowing.

Another method of the invention is to have the tags play the role of a host. A cocktail party host meets a guest, and takes her over to another guest and says "You two are both in the investment business." Then the host disappears and the two people can talk shop. The tags can perform this function. A tag does this social function without user interaction. When you meet another person at a gathering, the tags talk before you do. They search the data stored on each tag and try to figure out what you have in common with that person, if anything. It might be a hobby, an

interest, for example a popular book you have both read or a movie you have both seen, where you live, work, what sport you enjoy doing (or watching), etc. The common thing is displayed on the mutual tags. And if there is none, the other person's tag could say: "I'm not from Eau Claire, but I met someone 15 minutes ago who was." Particularly if the place is not common, or the hobby or interest is uncommon, the person being informed of the prior meeting will surely try to find that person.

If the tags have GPS receivers, it makes it much easier to find the person you would like to talk to, as wearer's locations would be sent to a central host through RFID, or if available on the tag, through WiFi or other radio communication, such as Bluetooth. GPS does not add a lot if RFID is used, as merely passing by an RFID reader already indicates your whereabouts. However, if a longer range radio is on board the tags, each wearer's whereabouts can be sent continually to a central database, which can be available to the tags through their radio receivers.

If GPS is on the tag, the tags can be used to provide a list of everyone within a certain number feet of the wearer of a tag (or within a certain number of feet of the person with whom she is talking). In a preferred embodiment, this can be accomplished through tag-to-tag proximity detection using an active radio system or range finder on the tag. Such a system is already in use in a system called "SpotMe." Unlike the invention, however, the SpotMe device is not a wearable device, but instead, operates like a PDA, and must be removed from the user's pocket for each desired interaction.

The names of the nearby people can appear on your tag or on the other person's tag. Or, you can enter a name and ask if that person is within a selected number of feet of you. You also can ask the tag to tell you if that person ever does come within 25 feet of you. When that happens, your tag can notify you by a light, beep or other method described earlier. The GPS information can also tell you in which direction to walk. The tag of the person you are facing can say: "Bob likes model trains, and is located 42 feet NW of you." All this is done by a tag using its computation powers to compare information it contains, has received from another tag, or in any other manner.

Another method of the invention is using the tags for a "people treasure hunt." For example, each person needs to find three others who are from Chicago. Or, you need to find one person who is from Chicago and likes broccoli. The data is most likely fed into the tag before the conference, as described earlier. Then, by communicating with various people, you narrow down your search, as described earlier, when the person you are talking to displays a message: "I'm not from Chicago, but I met someone two minutes ago who was." These clues allow you to find your "treasure" (the person from Chicago who likes broccoli).

In addition to facilitating social interaction, the tags can also be used for event management. They can keep track of which people attended which speeches, or the amount and type of interaction between people at the event. The tags can keep track, through the RFID readers at the entrances to rooms, who went where. If there are booths to be visited, each booth can have an RFID reader that will keep track of attendees. Since people may want to keep their detailed information confidential except when they wish to share it, the tags can be programmed only to automatically transmit only the persons name, or name and affiliation. If a person wants to share his business card (with email address, for example), the tag wearer can be required to press one of the buttons, and then that additional information will be transmitted.

The RFID reader at a booth can also supply information to a tag wearer, if desired by the wearer. By pushing a different button, for example, the tag can receive data about the company sponsoring the booth, or about its products. Alternatively, the staff at the booth can wear a tag, thereby capturing the business cards of everyone visiting the booth that consents to transmit his card information. The booth manager can gather information about the booth staffers from their tags, thereby ascertaining which staffers are most effective at meeting people and thereby getting them to share the more detailed business card type of data.

The attendee can use her own tag to indicate to a booth staffer's tag a request for follow-up product information (by pushing a button on the attendee's tag). Your own tag keeps a list of booths visited. Therefore, if desired, you do not need to directly tell the booth staffer your business card information. You can keep an automatic list of booths visited, and later use the tag to select the ones to whom you wish to send your card, or to send a request for further information from that booth.

When your tag gets turned in at the end of the conference, the data is collated and sent to each selected booth operator. Alternatively, as discussed above, that data can be scanned off your tag by an RFID reader during the event. The data may also be made available to attendees through a website after it has been scanned off the tags, so that an attendee who realizes long after an event that she should have asked for follow-up information can easily do so.

The tags can be used as "automatic" PDAs, and provide business card exchange when any two people meet. This can be programmed to be automatic, or require the push of a button, as discussed earlier. With the wearable tags of the invention, as opposed to PDAs, the interface is always present, whereas with a PDA, you have to take it out of your pocket first.

The tags provide many levels of information exchange. The first level is automatic. When you face someone who is also wearing a tag, your name (and perhaps your affiliation) appears on your tag for the other person to see. This is analogous to a simple name tag. When two people come up to each other, a message is shown with no time lapse, such as "We both like broccoli." The next level is consensual communication, where you hit a button to pass a business card to another tag. Another level is to use the tag to help remember people whom you have met (this is public, and not confidential information). To avoid meaningless lists, a timer is set, and only after 1 minute of IR interchange time, is the information, such as name and affiliation, recorded onto your tag and onto the other person's tag. This avoids collecting meaningless lists of people you passed in the hall, but did not meet. (Presumably you can get a list of all attendees from the conference administrator.) The tag can also use its timer to provide a time stamp of the time that each recorded meeting took place.

At the end of the event, you can get an email from the person administering the tags, who has read the data from your tag after the event. This email may contain, for example, two lists. The first will contain the people you have met (but with whom you did not do the full data exchange). That list will only have the person's name and affiliation. The other list contains the people with whom you did do the full data exchange, and will contain everything about those people that was selected for interchange.

Other useful information can be collected from the tags and distributed to attendees. For example, each person can receive data on the number of people that person met at the conference, along with the average number of people that each person at the conference met. If desired, this information can be computed and placed into the tags using the techniques described earlier, thus enabling two people, who are conversing, to be able to see on each other's tag how many people that person met at the conference, and also the number they met in common (including the names if that is useful). Data can also be kept (and/or displayed on the tags) on how many people one person met that another person has not yet met.

By compiling and distributing statistics, it can be determined whether a person is a relative introvert or extrovert (by comparing the number of people the tag wearer met to the average number met by each attendee). Thus, the relative size of the attendees' social networks can be computed and compared (e.g. you're connected to 100 people, but I'm only connected to 50). This provides feedback to the attendees on how well each one is connected to the social network at the event, and how their networking statistics compare to others.

The last level of communication is used to indicate interest in follow-up. When you are talking to a person, you, hit a different button (from the button used to approve full data interchange), and it flags that person for follow up. Then, after the conference, you get three lists: (1) the people you talked to; (2) the people you exchanged "cards" with; and (3) the people you intend, for some reason, to follow up with. If desired, there can be only two lists, with the follow up candidates asterisked. If you want, you can have an "urgent follow up" category, for example, by pressing the "follow-up" button twice. These features can be used when you visit a booth as well, either by the passerby or by the booth staff who are also wearing tags. The event planners can provide the same type of lists for the booth staffers. One example of consensual transmission is to flip up the tag, push a button, and the tag puts a check mark next to the name of the person you're talking to, indicating that you want to send your full contact information, such as email, phone, cell phone number, or whatever you choose in advance to send.

Radio or RFID signaling, using a strong signal from a central reader to one or to multiple tags, can be used to broadcast messages to everyone. Particularly if no

response is required, RFID can cover a broad area. Such a message can say that a speech is starting in 10 minutes, or has been delayed for 15 minutes, or that there is a fax waiting at the reception. Since the fax is individual to one tag, it may be sent with the wearer's tag ID, so only that wearer's tag will pick it up. The tags may be programmed to be selective, if desired, and only store messages directed to all tags, or only to that particular tag, but not messages directed to other tags. This broadcast feature can be used to broadcast event agendas, speaker biographies, lists of exhibitors or other commonly useful information.

The RFID-tag communication can record, in a central database, who has entered a room, who has left the room, and using that information, keep track of who is in the room, who attended a particular speech or visited a booth, who attended various meeting sessions and who did not. For example, professionals, such as doctors or lawyers, may only get credit "continuing education" credit for the conference if they attend certain speeches. The tags can be used to furnish the conference administrator with all that information, which can be relayed to the State Bar or Medical Board. Many conferences now employ auditors to provide independent verification of attendance to sponsors and exhibitors. The attendance data gathered by the tags will avoid the necessity of having such auditors.

Furthermore, there may be areas that only certain, pre-selected attendees may enter. When a person enters this area, an RFID reader can detect, from the person's tag, whether he is qualified to enter. If not, a buzzer can sound, or a person at the door can receive a signal indicating that the person entering is not qualified to do so. The person at door can then ask "Do you have ID?" A person that is not qualified may be refused entrance. Using this mode of operation, the tags can be used to store and transmit "digital tickets" to areas and events. These tickets can carry rules as to how they may be passed from one person to another. For an open party, tickets may replicate as they are passed from one person to another, leaving a ticket with the second person.

The amount of replication can be controlled, for example, if attendance is limited. One tag may only be able to provide three tickets, for example. After that, it is not possible to pass more tickets. The tickets may be passed automatically, or only if the tag wearer indicates a desire to invite the person he is talking with (in the same

manner, as described above, the full business card information is passed on). For strictly limited attendance, a ticket can only be passed, not replicated, so that it cannot be passed further by the recipient. And there may be rules as to the profile of those to whom tickets can be given (e.g., only to "gold level" partners, as discussed above). These tickets can be linked in to the security mechanism described above.

Another method of using the tags is in conjunction with personalized message boards. When you walk by a sign or advertisement, the sign automatically reads your tag (using any of the available methods of communication on your tag) and displays a personalized message. For example, at a conference, the dynamic message board can display: "The conference you signed up for starts in 5 minutes." Or, if you pre-registered for the conference, and answered "Toshiba" to the question of what laptop computer do you own, the board can display an advertisement for a WiFi adapter specifically designed for your Toshiba laptop. This would happen automatically as your tag came into communicating range (for example, IR or RFID) of the board. Or, the board can display a phone message for you.

Since the preferred embodiment of the tags of this invention have both RFID and IR communication, the message board can attempt to read both signals. If only the RFID signal was received by the board, and not the RF signal, the board would "know" you were not close enough for IR communication but were close enough for RFID communication, and can display your message in larger print so it can be read from afar. That could be a short message, such as "You have a phone call." As you get closer to the board, when IR communication is detected by the board, the print can become smaller and the message therefore can be more detailed, such as "Please call your mother on her cell phone at (999) 222-3454."

Since these tags are reusable, it is important that they be returned at the end of the conference or gathering. To be sure to get a tag returned, it is possible to display a notice on the tag timed with the tag's timer to flash or beep one-half hour before the event ends, for example, and display a message to return the tag. To enforce tag return, attendees can be notified (by the tag or otherwise) that they will not get an email with all their desired contact information unless the tag is returned. The RFID readers at the doors can also be connected to provide an alarm (such as is used to prevent shoplifting) if a person leaves the meeting area with her tag in her possession.

There are many other embodiments of the tag and the methods of communication using a tag of this invention that will be readily apparent to those skilled in the art. Therefore, the invention should only be limited as set forth in the claims which follow.

Agilent Technologies

APPENDIX A

IrDA® Data Compliant 115.2 kb/s 3 V to 5 V Infrared Transceiver

Technical Data

HSDL-3610#007
HSDL-3610#008

Features

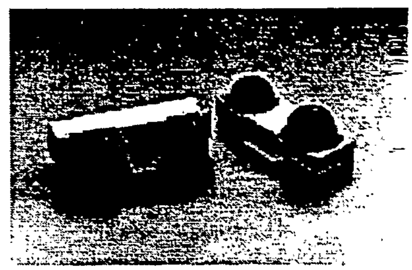
- **Fully Compliant to IrDA 1.0 Physical Layer Specifications**
  - 9.6 kb/s to 115.2 kb/s operation
- **Typical Link Distance > 1.5 m**
- **Compatible with HP-SIR and TV Remote**
- **IEC825-Class 1 Eye Safe**
- **Low Power Operation Range**
  - 2.7 V to 5.25 V
- **Small Module Size**
  - 4.0 x 12.2 x 5.1 mm (HxWxD)
- **Complete Shutdown**
  - TXD, RXD, PIN diode
- **Low Shutdown Current**
  - 10 nA typical
- **Adjustable Optical Power Management**
  - Adjustable LED drive- current to maintain link integrity
- **Integrated EMI Shield**
  - Excellent noise immunity
- **Edge Detection Input**
  - Prevents the LED from long turn-on time
- **Interface to Various Super I/O and Controller Devices**
- **Designed to Accommodate Light Loss with Cosmetic Window**
- **Only 2 External Components are Required**

Applications

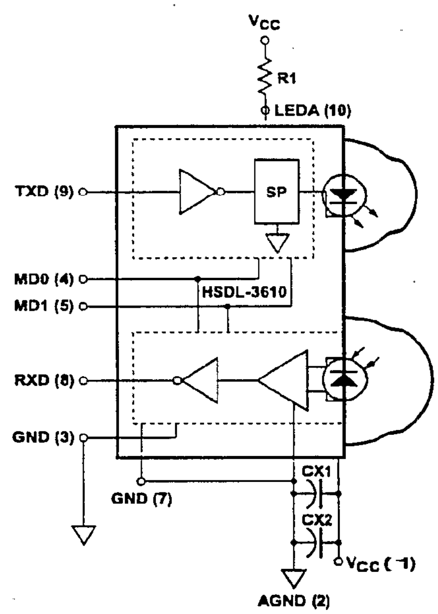
- **Digital Imaging**
  - Digital Still Cameras
  - Photo-Imaging Printers
- **Data Communication**
  - Notebook Computers
  - Desktop PCs
  - Win CE Handheld Products
  - Personal Digital Assistants (PDAs)
  - Printers
  - Fax Machines, Photocopiers
  - Screen Projectors
  - Auto PCs
  - Dongles
  - Set-Top Box
- **Telecommunication Products**
  - Cellular Phones
  - Pagers
- **Small Industrial & Medical Instrumentation**
  - General Data Collection Devices
  - Patient & Pharmaceutical Data Collection Devices

Description

The HSDL-3610 is a low-profile infrared transceiver module that provides interface between logic and IR signals for through-air, serial, half-duplex IR data link. The module is compliant to IrDA Data Physical Layer Specifications 1.0 and IEC825-Class 1 Eye Safe.



Functional Block Diagram



The HSDL-3610 contains a high-speed and high-efficiency 870 nm LED, a silicon PIN diode, and an integrated circuit. The IC contains an LED driver and a receiver providing a single output (RXD) for all data rates supported.

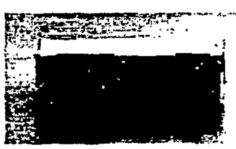
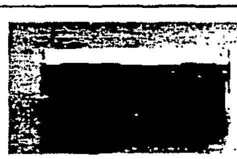
The HSDL-3610 can be completely shut down to achieve very low power consumption. In the shut down mode, the PIN diode will be inactive and thus producing very little photo-current even under very bright ambient light. The HSDL-3610 also incorporated the capability for adjustable optical power. With two programming pins; MODE 0 and MODE 1, the optical power output can be adjusted lower when the nominal desired link distance is one-third or two-third of the full IrDA link.

The HSDL-3610 comes in two package options; the front view option (HSDL-3610#007/#017), and the top view option (HSDL-3610#008/#018). Both options come with integrated shield that helps to ensure low EMI emission and high immunity to EMI field, thus enhancing reliable performance.

Application Support Information

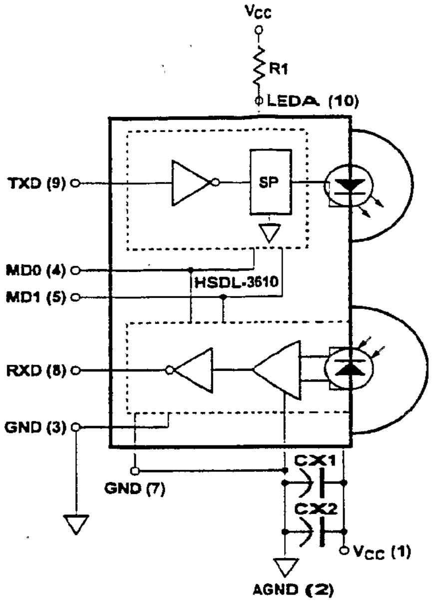
The Application Engineering group is available to assist you with the technical understanding associated with HSDL-3610 infrared transceiver module. You can contact them through your local sales representatives for additional details.

Ordering Information

Package Option	Package	Part Number	Standard Package Increment
	Front View	HSDL-3610#007	400
	Front View	HSDL-3610#017	10
	Top View	HSDL-3610#008	400
	Top View	HSDL-3610#018	10

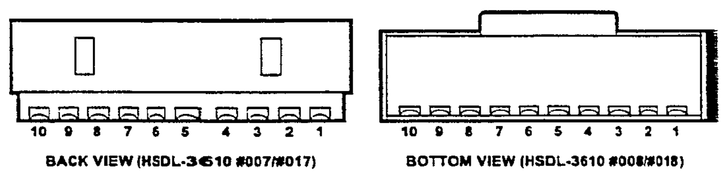
3

Functional Block Diagram



I/O Pins Configuration Table

Pin	Description	Symbol
1	Supply Voltage	Vcc
2	Analog Ground	AGND
3	Ground	GND
4	Mode 0	MD0
5	Mode 1	MD1
6	No Connection	NC
7	Ground	GND
8	Receiver Data Output	RXD
9	Transmitter Data Input	TXD
10	LED Anode	LEDA



Transceiver Control Truth Table

Mode 0	Mode 1	RX Function	TX Function
1	0	Shutdown	Shutdown
0	0	SIR	Full Distance Power
0	1	SIR	2/3 Distance Power
1	1	SIR	1/3 Distance Power

X = Don't Care

Transceiver I/O Truth Table

Transceiver Mode	Inputs		Outputs	
	TXD	EI	LED	RXD
Active	1	X	On	Not Valid
Active	0	High[1]	Off	Low[2]
Active	0	Low	Off	High
Shutdown	X[3]	Low	Not Valid	Not Valid

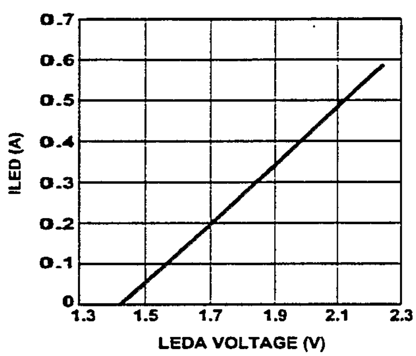
X= Don't Care EI = In-Band Infrared Intensity at detector

Notes:
1. In-Band EI ≤ 115.2 kb/s.
2. Logic Low is a pulsed response. The condition is maintained for duration dependent on the pattern and strength of the incident intensity.
3. To maintain low shutdown current, TXD needs to be driven high or low and not left floating.

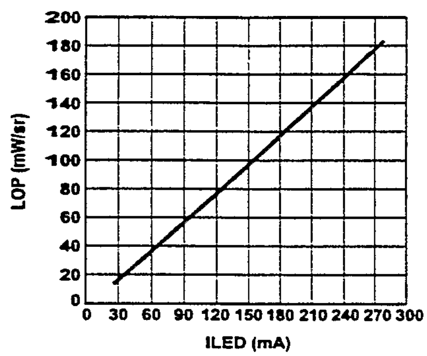
Recommended Application Circuit Components

Component	Recommended Value
R1	6.2 Ω ± 5%, 0.5 Watt, for 2.7 ≤ Vcc ≤ 3.6 V operation 15.0 Ω ± 5%, 0.5 Watt, for 4.75 ≤ Vcc ≤ 5.25 V operation
CX1[5]	0.47 μF ± 20%, X7R Ceramic
CX2[6]	6.8 μF ± 20%, Tantalum

Notes :
4. CX1 must be placed within 0.7 cm of the HSDL-3610 to obtain optimum noise immunity.
5. In environments with noisy power supplies, supply rejection performance can be enhanced by including CX2, as shown in "HSDL-3610 Functional Block Diagram" in page 3.



ILED vs. LEDA.



Light Output Power (LOP) vs. ILED.

Marking Information

The HSDL-3610#007/017 is marked "3610YYWW" on the shield where "YY" indicates the unit's manufacturing year, and "WW" refers to the work week in which the unit is tested.

The HSDL-3610#008/018 has no marking on the shield.

CAUTIONS: The BiCMOS inherent to the design of this component increases the component's susceptibility to damage from electrostatic discharge (ESD). It is advised that normal static precautions be taken in handling and assembly of this component to prevent damage and/or degradation which may be induced by ESD.

Absolute Maximum Ratings[6]

Parameter	Symbol	Minimum	Maximum	Unit	Conditions
Storage Temperature	T_S	-40	+100	°C	
Operating Temperature	T_A	-20	+70	°C	
DC LED Current	$I_{LED}(DC)$		165	mA	
Peak LED Current	$I_{LED}(PK)$		750	mA	≤ 2 µs pulse width, ≤ 10% duty cycle
LED Anode Voltage	V_{LEDA}	-0.5	7	V	
Supply Voltage	Vcc	0	7	V	
Transmitter Data Input Current	$I_{TXD}(DC)$	-12	12	mA	
Receiver Data Output Voltage	V_O	-0.5	Vcc+0.5	V	$\lvert I_O(RXD) \rvert = 20\ \mu A$

Note:
6. For implementations where case to ambient thermal resistance ≤ 50°C/W.

Recommended Operating Conditions

Parameter	Symbol	Minimum	Maximum	Unit	Conditions
Operating Temperature	T_A	-20	+70	°C	
Supply Voltage	Vcc	2.7	5.25	V	
Logic High Input Voltage for TXD, MD0, MD1, and FIR_SEL	V_{IH}	2 Vcc/3	Vcc	V	
Logic Low Transmitter Input Voltage	V_{IL}	0	Vcc/3	V	
LED (Logic High) Current Pulse Amplitude	I_{LEDA}	180	300	mA	
Receiver Signal Rate		2.4	115.2	kb/s	
Ambient Light					See IrDA Serial Infrared Physical Layer Link Specification, Appendix A for ambient levels

6

Electrical & Optical Specifications

Specifications hold over the Recommended Operating Conditions unless otherwise noted. Unspecified test conditions can be anywhere in their operating range. All typical values are at 25°C and 3.3 V unless otherwise noted.

Parameter		Symbol	Min.	Typ.	Max.	Unit	Conditions
Transceiver							
Supply Current	Shutdown	I_{CC1}		10	200	nA	$V_I(TXD) \leq V_{IL}$ or $V_I(TXD) \geq V_{IH}$
	Idle	I_{CC2}		2.5	5	mA	$V_I(TXD) \leq V_{IL}$, EI = 0
Digital Input Current	Logic Low/High	$I_{L/H}$	-1		1	µA	$0 \leq V_I \leq V_{CC}$
Transmitter							
Transmitter Radiant Intensity	Logic High Intensity	EI_H	50	120	400	mW/sr	$V_{IH} = 3.0$ V, $I_{LEDA} = 200$ mA, $\theta_{1/2} \leq 15°$
	Peak Wavelength	λ_P		875		nm	
	Spectral Line Half Width	$\Delta\lambda_{1/2}$		35		nm	
	Viewing Angle	$2\theta_{1/2}$	30		60	°	
	Optical Pulse Width	tpw (EI)	1.5	1.6	1.8	µs	tpw(TXD) = 1.6 µs at 115.2 kb/s
	Rise and Fall Times	t_r (EI), t_f (EI)			40	ns	tpw(TXD) = 1.6 µs at 115.2 kb/s, $t_{r/f}$(TXD) = 10 ns
	Maximum Optical Pulse Width	tpw (max)		20	50	µs	TXD pin stuck high
LED Anode On State Voltage		V_{ON}(LEDA)			2.4	V	$I_{LEDA} = 200$ mA, $V_I(TXD) \geq V_{IH}$
LED Anode Off State Leakage Current		I_{LK}(LEDA)		1	100	nA	$V_{LEDA} = V_{CC} = 5.25$ V, $V_I(TXD) \leq V_{IL}$

Electrical & Optical Specifications

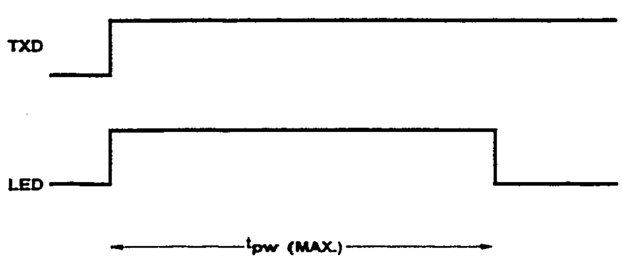
Specifications hold over the Recommended Operating Conditions unless otherwise noted. Unspecified test conditions can be anywhere in their operating range. All typical values are at 25°C and 3.3 V unless otherwise noted.

Parameter		Symbol	Min.	Typ.	Max.	Unit	Conditions
Receiver							
Receiver Data Output Voltage	Logic Low[8]	V_{OL}	0	-	0.4	V	I_{OL} = 1.0 mA, EI ≥ 3.6 μW/cm², $\theta_{1/2}$ ≤ 15°
	Logic High	V_{OH}	Vcc – 0.2	-	Vcc	V	I_{OH} = -20 μA, EI ≤ 0.3 μW/cm², $\theta_{1/2}$ ≤ 15°
	Viewing Angle	$2\theta_{1/2}$	30			°	
Logic High Receiver Input Irradiance		EI_H	0.0036		500	mW/cm²	For in-band signals ≤ 115.2 kb/s[7]
Logic Low Receiver Input Irradiance		EI_L			0.3	μW/cm²	For in-band signals[7]
Receiver Peak Sensitivity Wavelength		λ_P		880		nm	
Receiver SIR Pulse Width		tpw (SIR)	1		4.0	μs	$\theta_{1/2}$ ≤ 15°[9], C_L =10 pF
Receiver Latency Time		t_L		20	50	μs	
Receiver Rise/Fall Times		$t_{r/f}$ (RXD)		25		ns	
Receiver Wake Up Time		t_W			100	μs	[10]

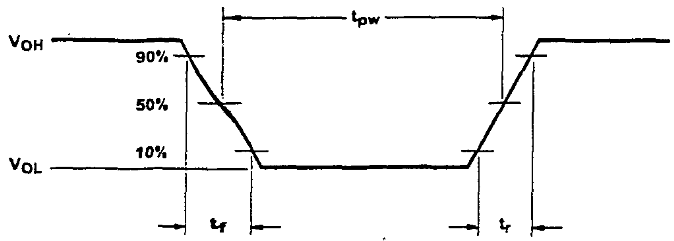
Notes:

7. An in-band optical signal is a pulse/sequence where the peak wavelength, λ_p, is defined as 850 ≤ λ_p ≤ 900 nm, and the pulse characteristics are compliant with the IrDA Serial Infrared Physical Layer Link Specification.
8. Logic Low is a pulsed response. The condition is maintained for duration dependent on pattern and strength of the incident intensity.
9. For in-band signals ≤ 115.2 kb/s where 3.6 μW/cm² ≤ EI ≤ 500 mW/cm².
10. Wake Up Time is the time between the transition from a shutdown state to an active state and the time when the receiver is active and ready to receive infrared signals.

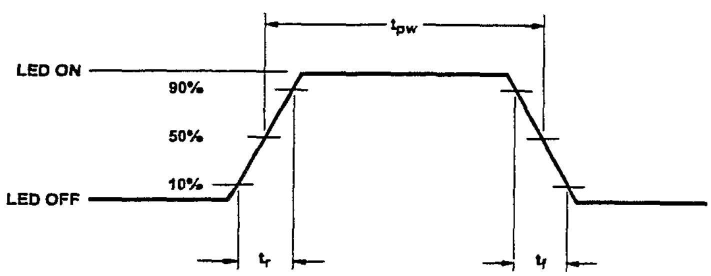
TXD "Stuck ON" Protection



RXD Output Waveform

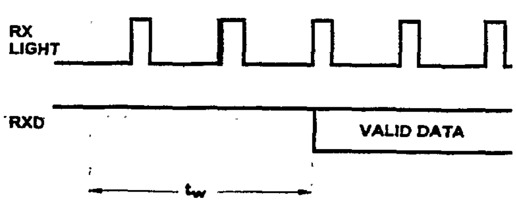


LED Optical Waveform



Receiver Wake Up Time Definition

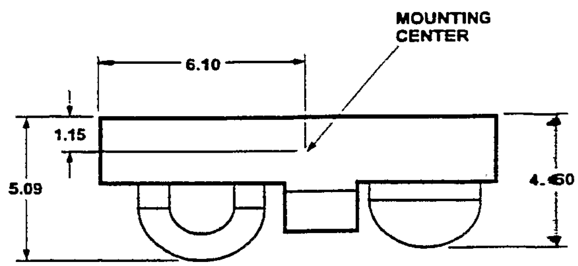
(when MD0 ≠ 1 and MD1 ≠ 0)



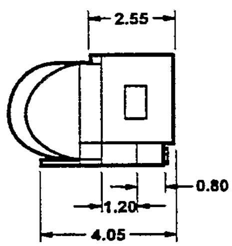
HSDL-3610#007 and HSDL3610#017 Package Outline with Dimension and Recommended PC Board Pad Layout

HSDL-3610#007/#017
(Front Option)

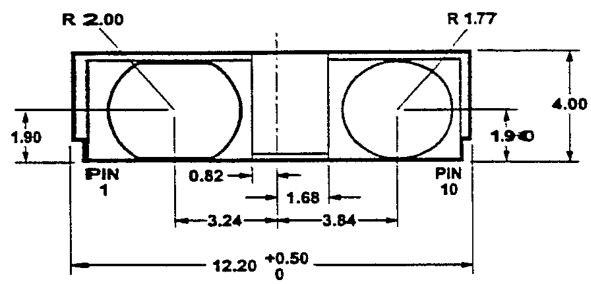
PIN	FUNCTION	PIN	FUNCTION
1	V_{CC}	6	NC
2	AGND	7	GND
3	GND	8	RXD
4	MD0	9	TXD
5	MD1	10	LEDA



TOP VIEW

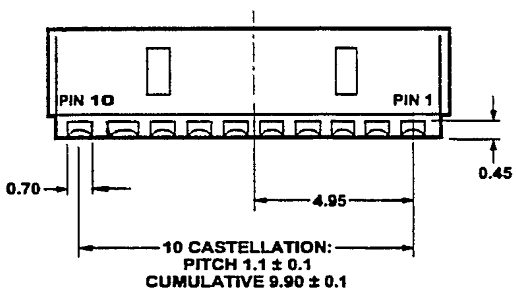


SIDE VIEW

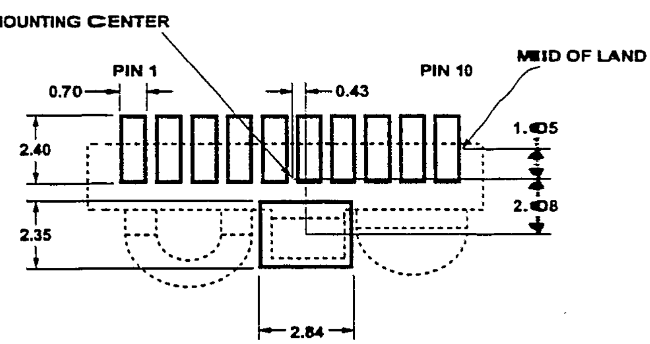


FRONT VIEW

ALL DIMENSIONS IN MILLIMETERS (mm).
DIMENSION TOLERANCE IS 0.20 mm
UNLESS OTHERWISE SPECIFIED.



BACK VIEW



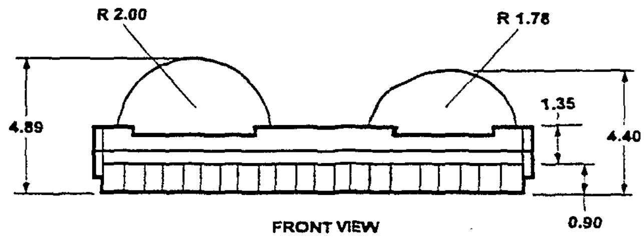
LAND PATTERN

HSDL-3610#008 and HSDL3610#018 Package Outline with Dimension and Recommended PC Board Pad Layout

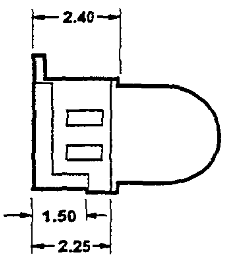
HSDL-3610#008/#018
(Top Option)

PIN	FUNCTION	PIN	FUNCTION
1	V_{CC}	6	NC
2	AGND	7	GND
3	GND	8	RXD
4	MD0	9	TXD
5	MD1	10	LEDA

LEGEND:
MC – MOUNTING CENTER
OC – OPTICAL CENTER

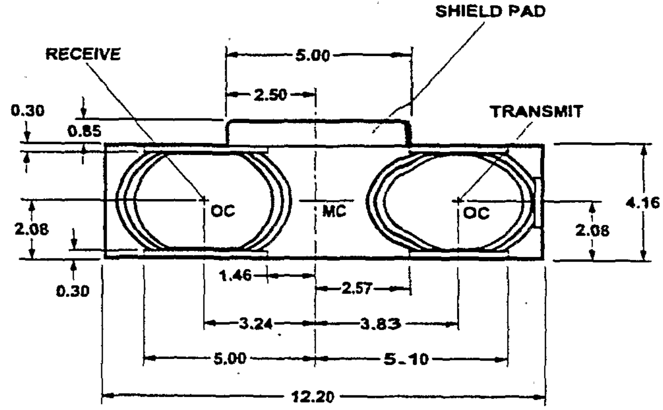


FRONT VIEW

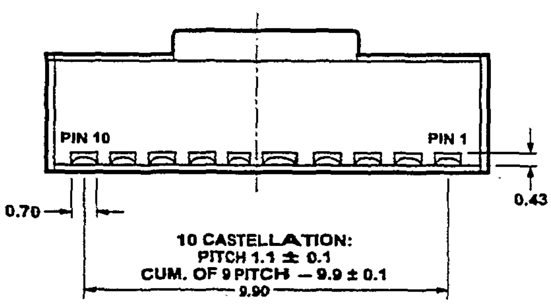


SIDE VIEW

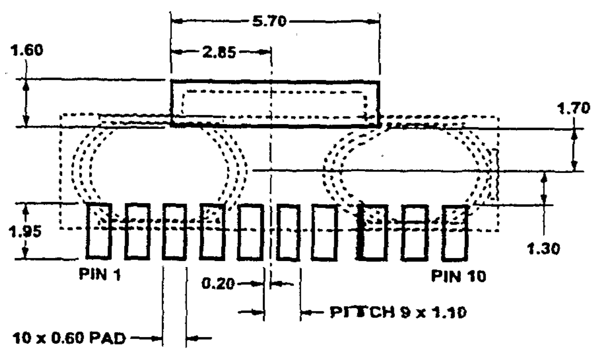
ALL DIMENSIONS IN MILLIMETERS (mm).
DIMENSION TOLERANCE IS 0.20 mm UNLESS OTHERWISE SPECIFIED.



TOP VIEW



BOTTOM VIEW

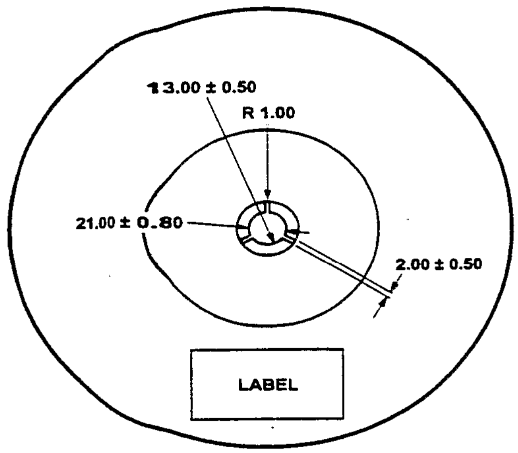


LAND PAD PATTERN

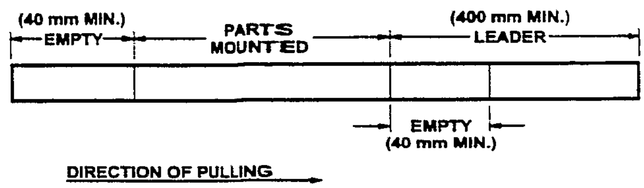
Tape and Reel Dimensions (HSDL-3610#007, #017)

All dimensions in millimeters (mm)

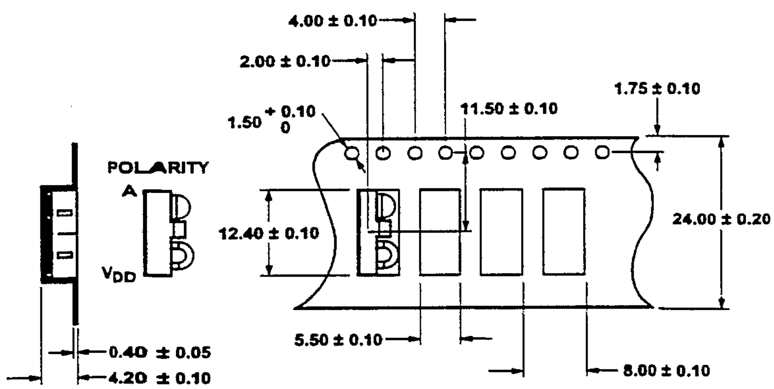
Quantity = 400 pieces per reel (HSDL-3610#007)
10 pieces per tape (HSDL-3610#017)



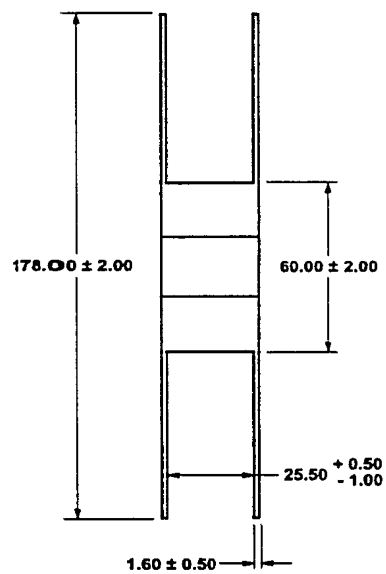
SHAPE AND DIMENSIONS OF REELS



CONFIGURATION OF TAPE



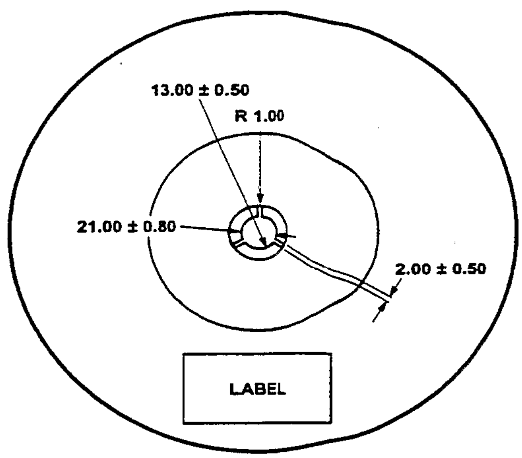
TAPE DIMENSIONS



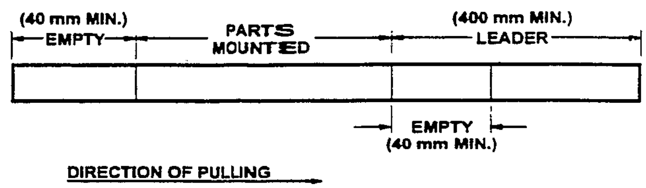
Tape and Reel Dimensions (HSDL-3610#008, #018)

All dimensions in millimeters (mm)

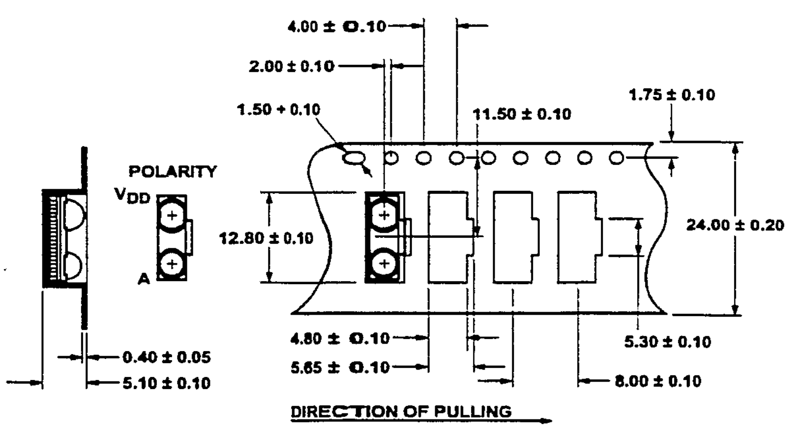
Quantity = 400 pieces per reel (HSDL-3610#008)
10 pieces per tape (HSDL-3610#018)



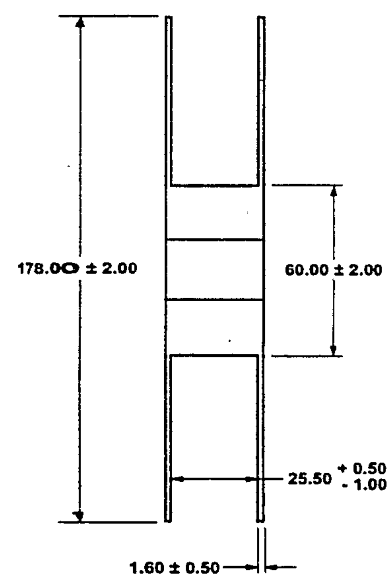
SHAPE AND DIMENSIONS OF REELS



CONFIGURATION OF TAPE

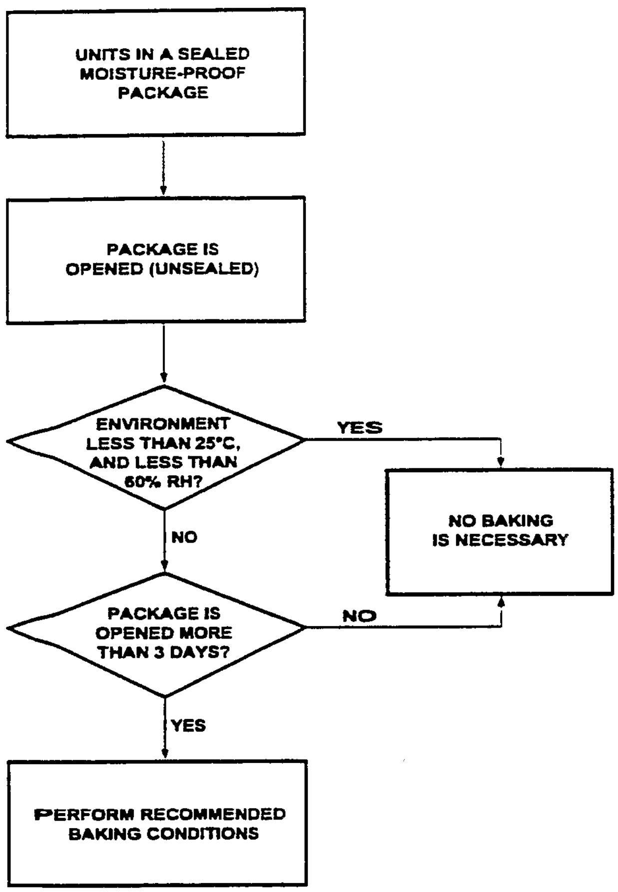


TAPE DIMENSIONS



Moisture Proof Packaging

All HSDL-3610 options are shipped in moisture proof package. Once opened, moisture absorption begins.



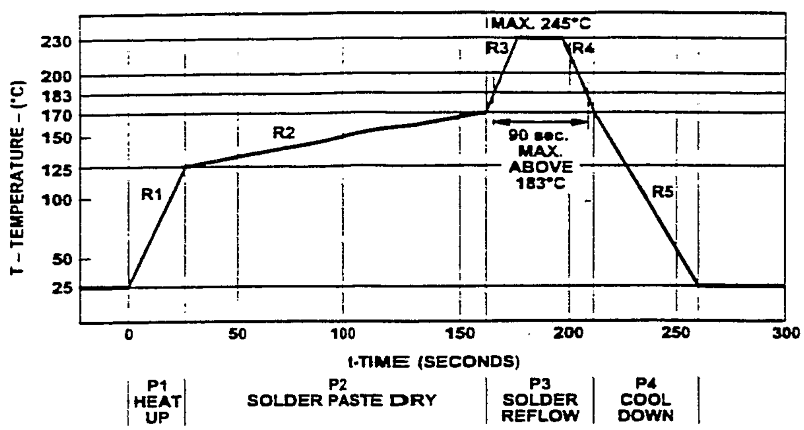
Baking Conditions

If the parts are not stored in dry conditions, they must be baked before reflow to prevent damage to the parts.

Package	Temperature	Time
In Reel	60°C	≥ 48 hours
In Bulk	100°C	≥ 4 hours
	125°C	≥ 2 hours

Baking should only be done once.

Reflow Profile



Process Zone	Symbol	ΔT	Maximum ΔT/Δtime
Heat Up	P1, R1	25°C to 125°C	4°C/s
Solder Paste Dry	P2, R2	125°C to 170°C	0.5 °C/s
Solder Reflow	P3, R3	170°C to 230°C (245°C at 10 seconds max.)	4°C/s
	P3, R4	230°C to 170°C	-4°C/s
Cool Down	P4, R5	170°C to 25°C	-3°C/s

The reflow profile is a straight-line representation of a nominal temperature profile for a convective reflow solder process. The temperature profile is divided into four process zones, each with different ΔT/Δtime temperature change rates. The ΔT/Δtime rates are detailed in the above table. The temperatures are measured at the component to printed circuit board connections.

In **process zone P1**, the PC board and HSDL-3610 castellation I/O pins are heated to a temperature of 125°C to activate the flux in the solder paste. The temperature ramp up rate, R1, is limited to 4°C per second to allow for even heating of both the PC board and HSDL-3610 castellation I/O pins.

Process zone P2 should be of sufficient time duration (> 60 seconds) to dry the solder paste. The temperature is raised to a level just below the liquidus point of the solder, usually 170°C (338°F).

Process zone P3 is the solder reflow zone. In zone P3, the temperature is quickly raised above the liquidus point of solder to 230°C (446°F) for optimum results. The dwell time above the liquidus point of solder should be between 15 and 90 seconds. It usually takes about 15 seconds to assure proper coalescing of the solder balls into liquid solder and the formation of good solder connections. Beyond a dwell time of 90 seconds, the intermetallic growth within the solder connections becomes excessive, resulting in the formation of weak and unreliable connections. The temperature is then rapidly reduced to a point below the solidus temperature of the solder, usually 170°C (338°F), to allow the solder within the connections to freeze solid.

Process zone P4 is the cool down after solder freeze. The cool down rate, R5, from the liquidus point of the solder to 25°C (77°F) should not exceed -3°C per second maximum. This limitation is necessary to allow the PC board and HSDL-3610 castellation I/O pins to change dimensions evenly, putting minimal stresses on the HSDL-3610 transceiver.

Appendix A: Test Method

A1. Background Light and Electromagnetic Field

There are four ambient interference conditions in which the receiver is to operate correctly. The conditions are to be applied separately:

1. Electromagnetic field:
3 V/m maximum (please refer to IEC 801-3, severity level 3 for details).

2. Sunlight:
10 kilolux maximum at the optical port. This is simulated with an IR source having a peak wavelength within the range of 850 nm to 900 nm and a spectral width of less than 50 nm biased to provide 490 μW/cm^2 (with no modulation) at the optical port. The light source faces the optical port.

This simulates sunlight within the IrDA spectral range. The effect of longer wavelength radiation is covered by the incandescent condition.

3. Incandescent Lighting:
1000 lux maximum. This is produced with general service, tungsten-filament, gas-filled, inside frosted lamps in the 60 Watt to 100 Watt range to generate 1000 lux over the horizontal surface on which the equipment under test rests. The light sources are above the test area. The source is expected to have a filament temperature in the 2700 to 3050 Kelvin range and a spectral peak in the 850 to 1050 nm range.

4. Fluorescent Lighting:
1000 lux maximum. This is simulated with an IR source having a peak wavelength within the range of 850 nm to 900 nm and a spectral width of less than 50 nm biased and modulated to provide an optical square wave signal (0 μW/cm^2 minimum and 0.3 μW/cm^2 peak amplitude with 10% to 90% rise and fall times less than or equal to 100 ns) over the horizontal surface on which the equipment under test rests. The light sources are above the test area. The frequency of the optical signal is swept over the frequency range from 20 kHz to 200 kHz.

Due to the variety of fluorescent lamps and the range of IR emissions, this condition is not expected to cover all circumstances. It will provide a common floor for IrDA operation.

All IR transceivers operating under the recommended drive conditions are classified as CENELEC EN60825-1 Accessible Emission Limit (AEL) Class 1. This standard is in effect in Europe as of January 1, 1997. AEL Class 1 LED devices are considered eye safe. Please see Application Note 1094 for more information.

Appendix B: HSDL-3610#007/#017 SMT Assembly Application Note

1.0 Solder Pad, Mask and Metal Solder Stencil Aperture

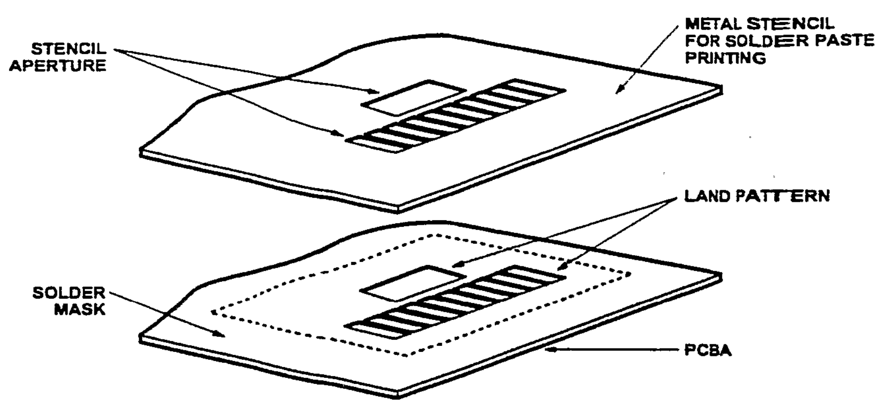


Figure 1.0. Stencil and PCBA.

1.1 Recommended Land Pattern for HSDL-3610#007/#017

Dim.	mm	Inches
a	2.40	0.095
b	0.70	0.028
c (pitch)	1.10	0.043
d	2.35	0.093
e	2.80	0.110
f	3.13	0.123
g	4.31	0.170

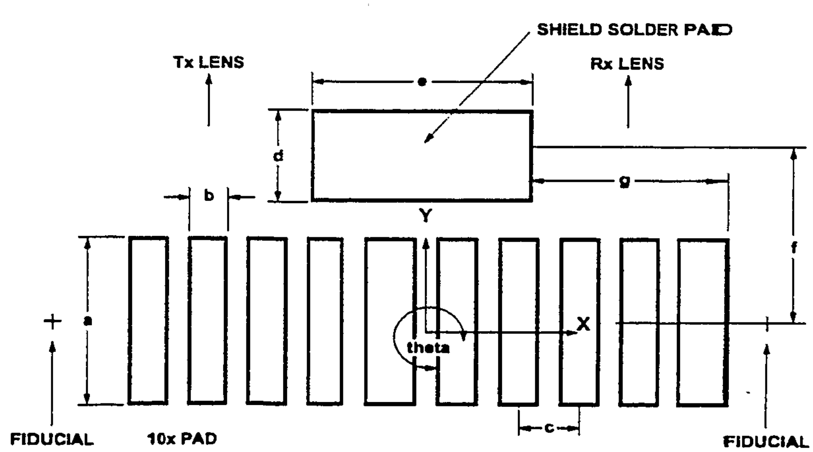


Figure 2.0. Top View of Land Pattern.

1.2 Adjacent Land Keep-out and Solder Mask Areas

Dim.	mm	Inches
h	min. 0.2	min. 0.008
j	13.4	0.528
k	4.7	0.185
l	3.2	0.126

- Adjacent land keep-out is the **maximum space** occupied by the unit relative to the land pattern. There should be no other SMD components within this area.
- "**h**" is the minimum solder resist strip width required to avoid solder bridging adjacent pads.
- It is recommended that 2 fiducial cross be placed at mid-length of the pads for unit alignment.

Note: Wet/Liquid Photo-Imaginable solder resist/mask is recommended.

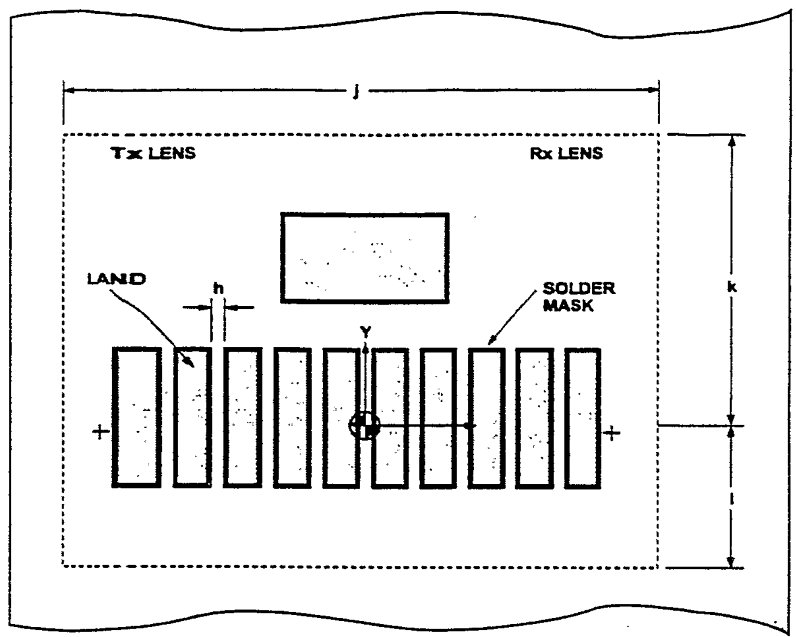


Figure 3.0. HSDL-3610#007/#017 PCBA – Adjacent Land Keep-out and Solder Mask.

2.0 Recommended Solder Paste/cream Volume for Castellation Joints

Based on calculation and experiment, the printed solder paste volume required per castellation pad is 0.30 cubic mm (based on either no-clean or aqueous solder cream types with typically 60 to 65% solid content by volume).

2.1 Recommended Metal Solder Stencil Aperture

It is recommended that only 0.152 mm (0.006 inches) or 0.127 mm (0.005 inches) thick stencil be used for solder paste printing. This is to ensure adequate printed solder paste volume and no shorting. The following combination of metal stencil aperture and metal stencil thickness should be used:

See Fig 4.0			
t, nominal stencil thickness		***l, length of aperture***	
mm	**inches**	**mm**	**inches**
0.152	0.006	2.8 ± 0.05	0.110 ± 0.002
0.127	0.005	3.4 ± 0.05	0.134 ± 0.002
w, the width of aperture is fixed at 0.70 mm (0.028 inches)			
Aperture opening for shield pad is 2.8 mm x 2.35 mm as per land dimensions			

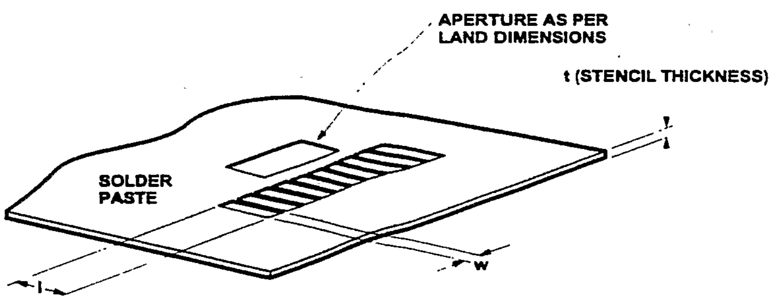


Figure 4.0. Solder Paste Stencil Aperture.

3.0 Pick and Place Misalignment Tolerance and Product Self-Alignment after Solder Reflow

If the printed solder paste volume is adequate, **the unit will self-align** in the X-direction after solder reflow. Units should be properly reflowed in IR Hot Air convection oven using the recommended reflow profile. The direction of board travel does not matter.

Allowable Misalignment Tolerance

X – direction	≤ 0.2 mm (0.008 inches)
***Theta* – direction**	± 2 degrees

3.1 Tolerance for X-axis Alignment of Castellation

Misalignment of castellation to the land pad should not exceed 0.2 mm or approximately half the width of the castellation during placement of the unit. The castellations will completely self-align to the pads during solder reflow as seen in the pictures below.

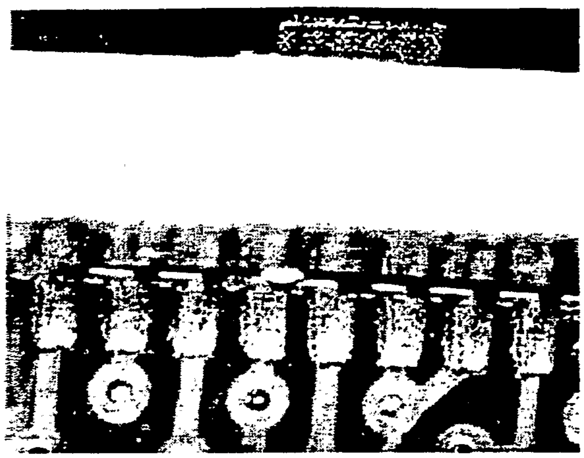


Photo 1.0. Castellation misaligned to land pads in x-axis before reflow.

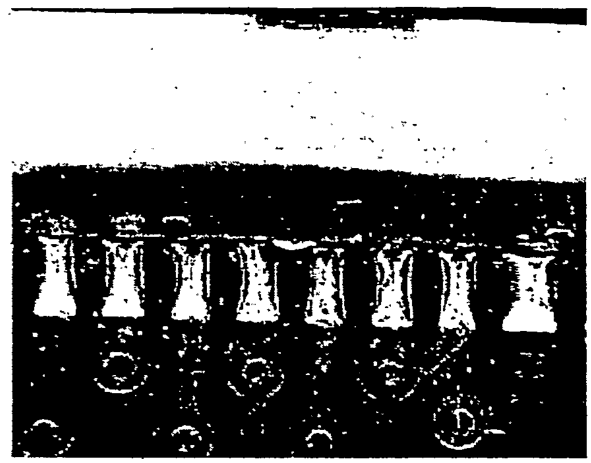


Photo 2.0. Castellation self-align to land pads after reflow.

3.2 Tolerance for Rotational (Theta) Misalignment

Units when mounted should not be rotated more than ± 2 degrees with reference to center X-Y as specified in Fig 2.0. Pictures 3.0 and 4.0 show units before and after reflow. Units with a Theta misalignment of more than 2 degrees do not completely self align after reflow. Units with ± 2 degree rotational or Theta misalignment self-aligned completely after solder reflow.

Photo 3.0. Unit is rotated before reflow.

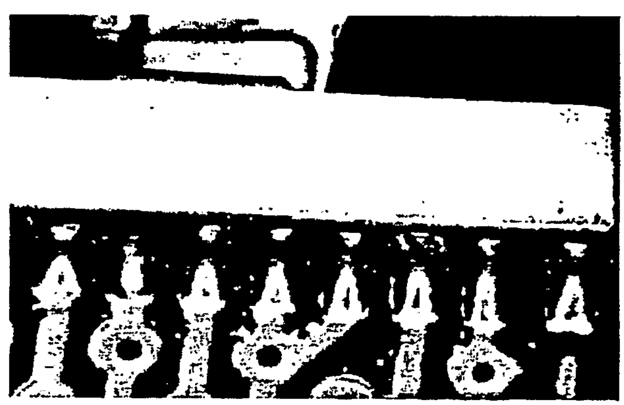


Photo 4.0. Unit self-aligns after reflow.

3.3 Y-axis Misalignment of Castellation

In the Y-direction, the unit does not self-align after solder reflow. It is recommended that the unit be placed in line with the fiducial mark (mid-length of land pad.) This will enable sufficient land length (minimum of 1/2 land length.) to form a good joint. See Fig 5.0.

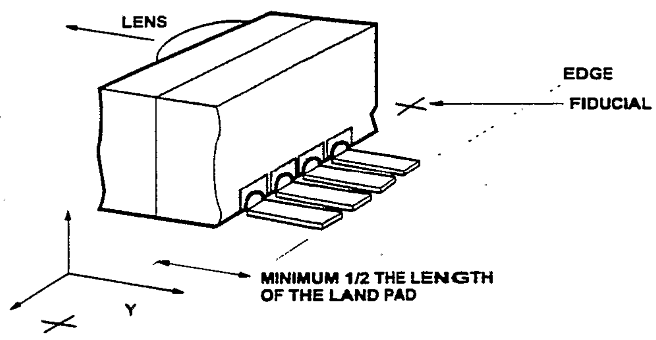


Figure 5.0. Section of a Castellation in Y-axis.

3.4 Example of Good HSDL-3610#007/#017 Castellation Solder Joints

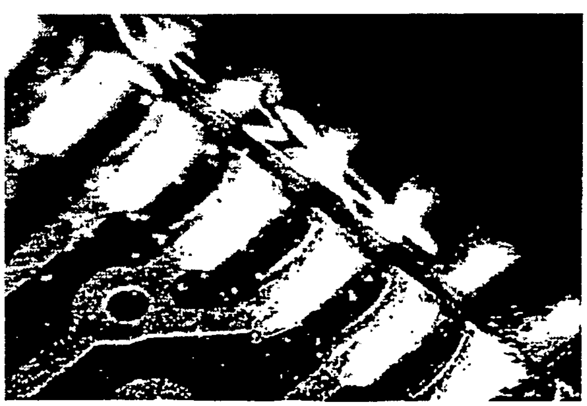
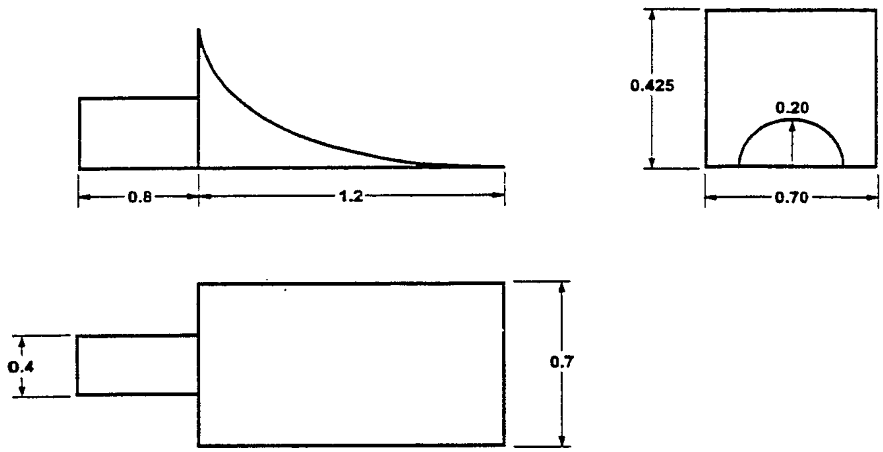


Photo 5.0. Good Solder Joint.

This joint is formed when the printed solder paste volume is adequate, i.e. 0.30 cubic mm and reflowed properly. It should be reflowed in IR Hot-air convection reflow oven. Direction of board travel does not matter.

4.0 Solder Volume Evaluation and Calculation

Geometry of an HSDL-3610#007/#017 solder fillet.



Appendix C : HSDL-3610#008/#018 SMT Assembly Application Note

1.0 Solder Pad, Mask and Metal Solder Stencil Aperture

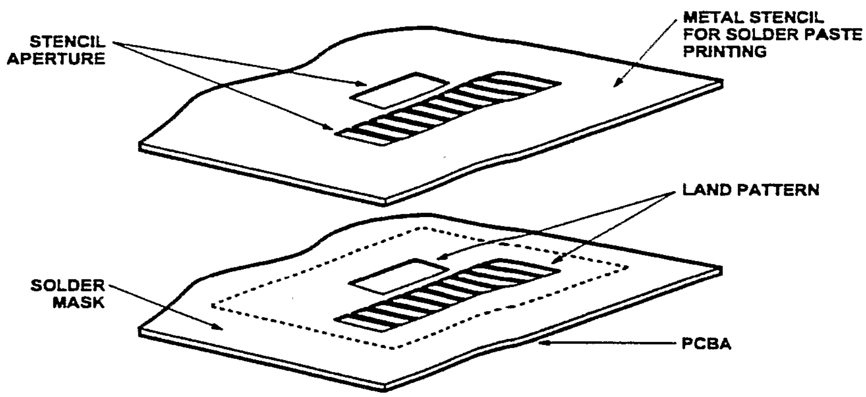


Figure 1.0. Stencil and PCBA.

1.1 Recommended Land Pattern for HSDL-3610#008/#018

Dim.	mm	Inches
a	1.95	0.077
b	0.60	0.024
c (pitch)	1.10	0.043
d	1.60	0.063
e	5.70	0.224
f	3.80	0.150
g	2.40	0.094
h	0.80	0.032

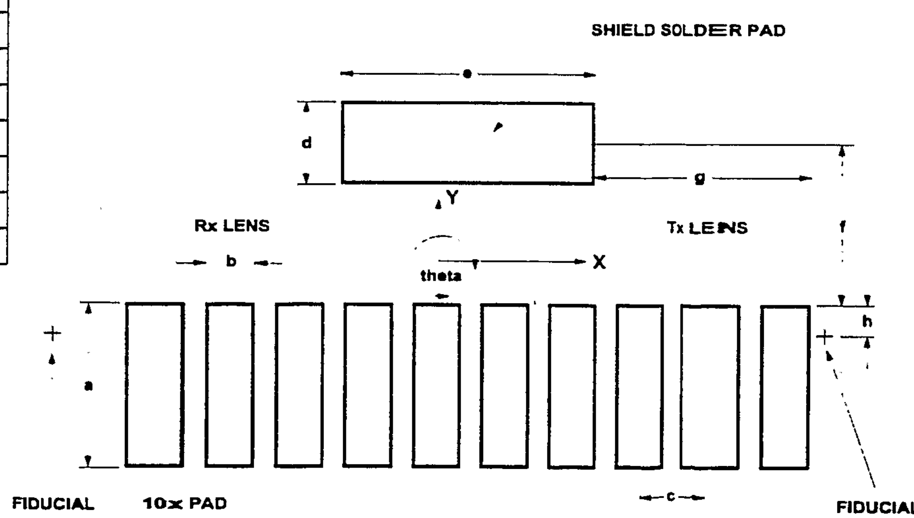


Figure 2.0. Top View of Land Pattern.

1.2 Adjacent Land Keep-out and Solder Mask Areas

Dim.	mm	Inches
h	min. 0.2	min. 0.008
j	13.4	0.528
k	5.8	0.228
l	3.5	0.130

- Adjacent land keep-out is the **maximum space** occupied by the unit relative to the land pattern. There should be no other SMD components within this area.
- "**h**" is the minimum solder resist strip width required to avoid solder bridging adjacent pads.
- It is recommended that 2 fiducial cross be placed at mid-length of the pads for unit alignment.

Note: Wet/Liquid Photo-Imaginable solder resist/mask is recommended.

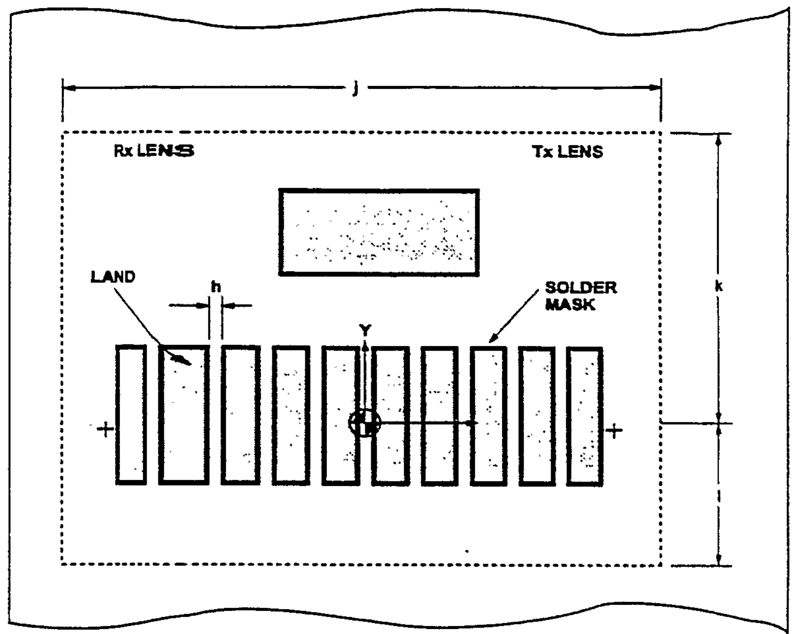


Figure 3.0. HSDL-3610#008/#018 PCBA – Adjacent Land Keep-out and Solder Mask.

2.0 Recommended Solder Paste/cream Volume for Castellation Joints

Based on calculation and experiment, the printed solder paste volume required per castellation pad is 0.28 cubic mm (based on either no-clean or aqueous solder cream types with typically 60 to 65% solid content by volume).

2.1 Recommended Metal Solder Stencil Aperture

It is recommended that only 0.152 mm (0.006 inches) or 0.127 mm (0.005 inches) thick stencil be used for solder paste printing. This is to ensure adequate printed solder paste volume and no shorting. The following combination of metal stencil aperture and metal stencil thickness should be used:

See Fig 4.0			
t, nominal stencil thickness		***l, length of aperture***	
mm	**inches**	**mm**	**inches**
0.152	0.006	3.1 ± 0.05	0.122 ± 0.002
0.127	0.005	3.7 ± 0.05	0.147 ± 0.002
w, the width of aperture is fixed at 0.60 mm (0.024 inches)			
Aperture opening for shield pad is 5.7 mm x 1.6 mm as per land dimensions			

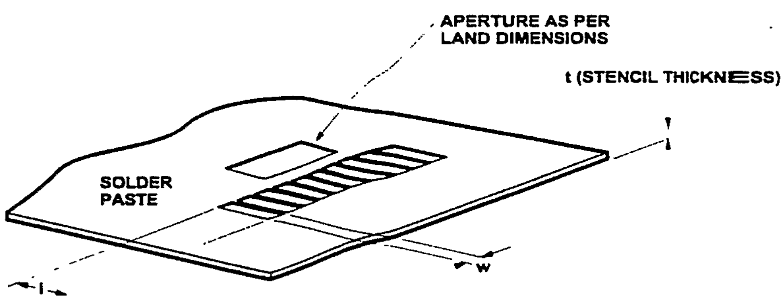


Figure 4.0. Solder Paste Stencil Aperture.

3.0 Pick and Place Misalignment Tolerance and Product Self-Alignment after Solder Reflow

If the printed solder paste volume is adequate, **the unit will self-align** in X-direction after solder reflow. Units should be properly reflowed in IR Hot Air convection oven using the recommended reflow profile. The direction of board travel does not matter.

Allowable Misalignment Tolerance

X – direction	≤ 0.2 mm (0.008 inches)

3.1 Tolerance for X-axis Alignment of Castellation

Misalignment of castellation to the land pad should not exceed 0.2 mm or approximately half the width of the castellation during placement of the unit. The castellations will completely self-align to the pads during solder reflow as seen in the pictures below.

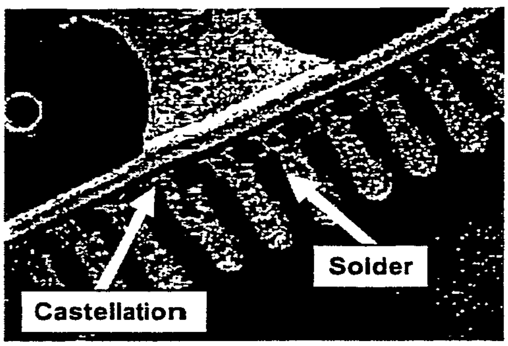


Photo 1.0. Castellation mis-aligned to land pads in X-axis before reflow.

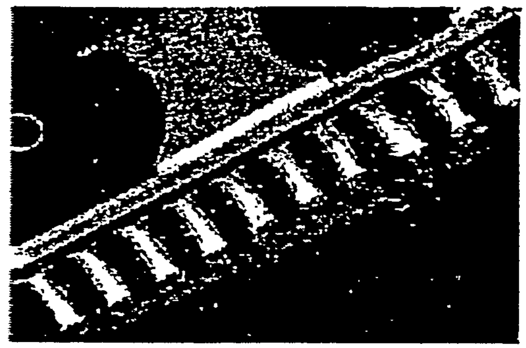


Photo 2.0. Castellation self-aligned to land pads after reflow.

3.2 Tolerance for Rotational (Theta) Misalignment

Units when mounted should not be rotated more than ± 1 degrees with reference to center X-Y as specified in Fig 2.0. Pictures 3.0 and 4.0 show that unit cannot be self-aligned back due to the small wetting force. Units with a Theta misalignment of more than 1 degree do not completely self align after reflow.

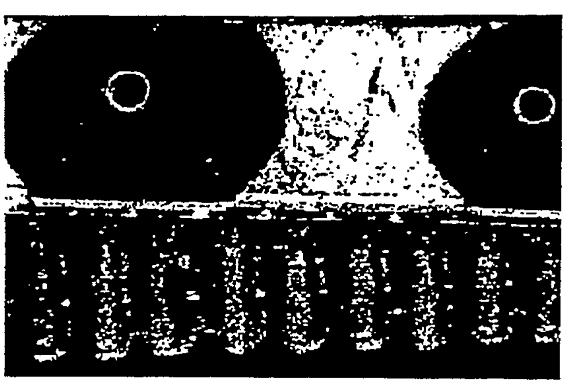


Photo 3.0. Unit is rotated before reflow.

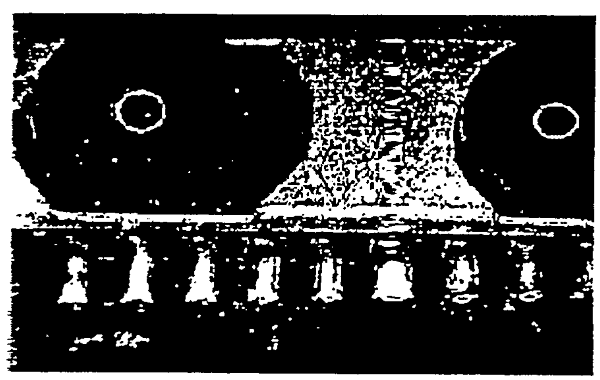


Photo 4.0. Unit not self-aligned after reflow.

3.3 Y-axis Misalignment of Castellation

In the Y-direction, the unit does not self align after solder reflow. It is recommended that the unit be placed in line with the fiducial mark. This will enable sufficient land length to form a good joint. See Fig. 5.0.

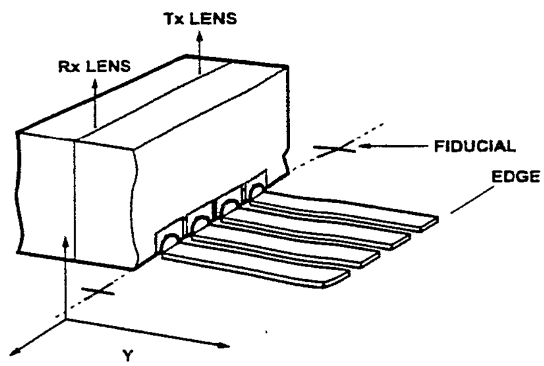


Figure 5.0. Section of a Castellation in Y-axis.

3.4 Example of Good Castellation Solder Joints

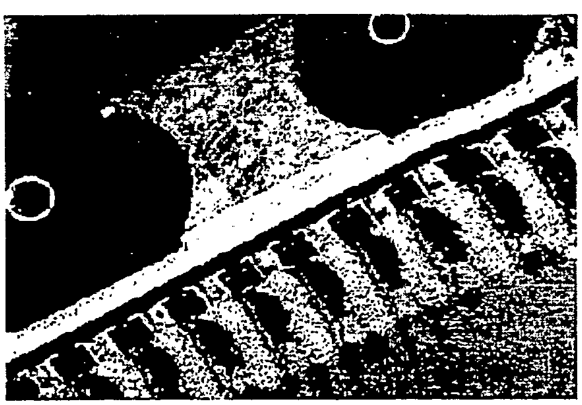


Photo 6.0. Good Attachment before Reflow.

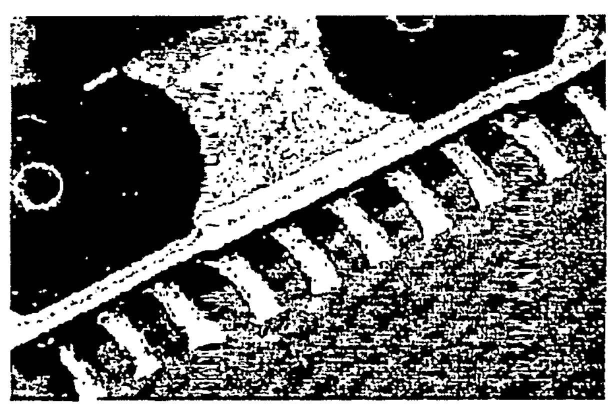
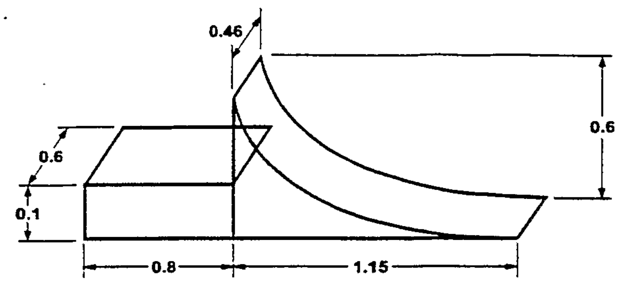


Photo 7.0. Good Solder Joint after Reflow.

This joint is formed when the printed solder paste volume is adequate, i.e. 0.30 cubic mm and reflowed properly. It should be reflowed in IR Hot-air convection reflow oven. Direction of board travel does not matter.

4.0 Solder Volume Evaluation and Calculation

Geometry of an HSDL-3610#008/#018 solder fillet.



V_{solder} = (0.8 x 0.6 x 0.1) + (0.5 x 0.6 x 0.46 (0.6 + 1.15)/2) = 0.1662 mm^3

V_{paste} = V_{solder}/0.6 = 0.277 mm^3

Agilent Technologies

www.semiconductor.agilent.com

Data subject to change.

March 13, 2001
Obsoletes 5980-1767E (6/00)
5988-2314EN

Published June 1, 2002. Distribution restricted to Sponsors until September 1, 2002.

APPENDIX B

AUTO-ID CENTER

WHITE PAPER

Multi-Band, Low-Cost EPC Tag Reader

Matthew Reynolds, Joseph Richards, Sumukh Pathare, Harry Tsai, Yael Maguire, Rehmi Post, Ravikanth Pappu, Bernd Schoner

AUTO-ID CENTER MASSACHUSETTS INSTITUTE OF TECHNOLOGY, 77 MASSACHUSETTS AVENUE, BLDG 3-449, CAMBRIDGE, MA 02139-4307, USA

ABSTRACT

In collaboration with the Auto-ID Center, ThingMagic LLC has developed a unique multi-band RFID tag reader reference platform. This reader has been designed to read tags conforming to the the Auto-ID Center's emerging EPC specifications at both the 13.56MHz (HF) and 902 – 928MHz (UHF) frequency bands. The hardware architecture consists of a general purpose analog front end up/downconverter for each band, followed by a software radio architecture allowing easy adaptation to new frequencies and protocols. The reader's modular software architecture allows easy expansion while at the same time providing sophisticated networking capabilities including Web configurability, dynamic firmware update, and a TCP/IP reader interface by means of an embedded SQL-compatible data base engine. This design offers excellent scalability and flexibility allowing rapid deployment and an in-situ upgrade path.

Published June 1, 2002. Distribution restricted to Sponsors until September 1, 2002.

WHITE PAPER

Multi-Band, Low-Cost EPC Tag Reader

Biography

Matt Reynolds
Partner, ThingMagic

Matt Reynolds is an electrical engineer specializing in wireless communication systems. He has designed remote sensing and communication systems that have been deployed successfully at the south summit of Mt. Everest, on the Embree Glacier in Antarctica, in rural South America, and underwater in MIT's ORCA robotic submarine. Matt's research interests include low power wireless systems, embedded communications and networking, radiolocation systems, electronic circuits and devices, and digital signal processing. He is a Ph.D. candidate and Motorola Fellow at the MIT Media Lab, and holds S.B. and M.Eng. degrees in electrical engineering and computer science from MIT.

Joseph Richards
Project Engineer, ThingMagic

Joey Richards received the Master of Engineering degree in electrical engineering and computer science from MIT. While at MIT, Joey studied communication systems, RF design and modeling, and nonlinear dynamics. His engineering experience includes developing GPS signal processing firmware, designing real-time sensor networks, and programming at all levels from hand-coded assembly for embedded processors to PC applications. He also holds Bachelor's degrees in physics and electrical engineering and computer science from MIT.

Sumukh Pathare
Project Engineer, ThingMagic

Sumukh Pathare holds a M.S. degree in Mechanical Engineering from the University of Massachusetts, Amherst and a B.Tech. degree in Engineering Physics from the Indian Institute of Technology, Bombay. His principal field of expertise is embedded hardware and firmware design. He has developed digital and analog hardware and embedded firmware for various applications including robotics, telephony, optical networking and most recently for RFID.

Published June 1, 2002. Distribution restricted to Sponsors until September 1, 2002.

WHITE PAPER

Multi-Band, Low-Cost EPC Tag Reader

Biography

Yael Maguire
Partner, ThingMagic

Yael Maguire is interested in the fundamental ties between information processing and physics, signal processing and nontraditional computing devices. He has modeled oil pipeline robots and worked on software and electronics for aided inertial guidance systems. Recently, Yael worked on advanced web programming and sensor fusion in collaboration with the UnPrivate House exhibit at the Museum of Modern Art in New York. He has an undergraduate degree in Engineering Physics from Queen's University in Canada and holds a master's in Media Arts and Sciences from MIT.

Harry Tsai
Project Engineer, ThingMagic

Harry Tsai holds Bachelor and Master of Engineering degrees in Electrical Engineering and Computer Science from MIT. He did his graduate work at the MIT Artificial Intelligence Laboratory and previously worked for an AI Lab spinoff specializing in resource allocation software for the airport industry.

Rehmi Post
Partner, ThingMagic

Rehmi Post's research interests are in inertial sensing, dynamics of micro- and mesoscale systems, and MEMS. At the MIT Media Lab, where Rehmi is currently a PhD candidate, he also earned an M.Sc. for the development of e-broidery, a means of fabricating electronic circuitry on wearable textile substrates. Rehmi also holds a B.Sc. in Physics from the University of Massachusetts, where he studied condensed-matter systems and worked with the Tuominen Nanostructures Lab developing superconducting single-electron devices.

Published June 1, 2002. Distribution restricted to Sponsors until September 1, 2002.

WHITE PAPER

Multi-Band, Low-Cost EPC Tag Reader

Biography

Ravi Pappu
Partner, ThingMagic

Ravi Pappu received his Ph.D. from the Physics and Media Group at the MIT Media Lab for his work on designing and implementing inexpensive systems for cryptographic authentication. While at MIT, he co-created the first dynamic holographic video system with haptic interaction. His technical interests are in physical cryptography, optical engineering, and display technology. Ravi holds a B.S. in electronics and communication engineering from Osmania University, India, an M.S. in electrical engineering from Villanova, and a M.S. in Media Arts and Sciences from MIT.

Bernd Schoner
Managing Partner, ThingMagic

Elektrizitätskünstler Bernd Schoner's expertise includes time series prediction, nonlinear estimation, stochastic processes, machine learning, neural networks, and audio processing. His research has led to devices and software applications as unique as the Marching Cello, a wearable instrument providing the functionality of a cello, and a giant polyphonic floorboard for the Flying Karamazov Brothers. Bernd holds a Diplom-Ingenieur from RWTH Aachen, Germany, and an Ingénieur des Arts et Métiers from Ecole Centrale de Paris, France. He received his Ph.D. from the MIT Media Laboratory in 2000.

Published June 1, 2002. Distribution restricted to Sponsors until September 1, 2002.

WHITE PAPER

Multi-Band, Low-Cost EPC Tag Reader

Contents

Published June 1, 2002. Distribution restricted to Sponsors until September 1, 2002.

1. INTRODUCTION

ThingMagic LLC has been working cooperatively with the Auto-ID Center and its members to design and prototype a new breed of RFID reader based on the Auto-ID Center's open-standards philosophy. The architecture of this reader is based on the realization that the RFID reader of the future is not merely a radio transceiver with a serial port; instead, the Auto-ID Center's vision of a supply chain managed with the help of RFID technology requires a fundamental change in both the hardware and the software capabilities of an RFID reader. Under the Auto-ID Center's vision, RFID readers will be installed on every factory floor, warehouse shelf, retail shelf, entry point and exit point to track every product through its entire pre-consumer life cycle. Most existing readers fail the crucial tests of scalability for these applications. We must therefore draw a distinction between the RFID readers of the past and the new generation of RFID readers required to meet these very important supply chain challenges.

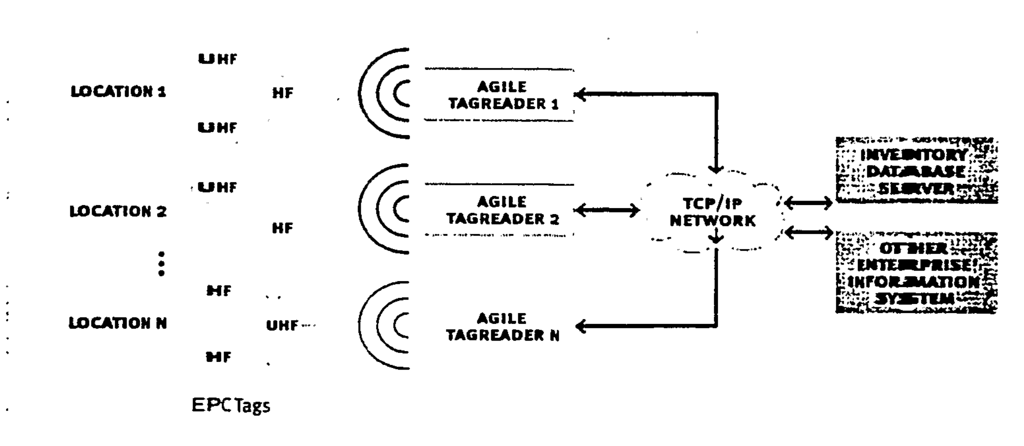
In the model of the past, an RFID reader is an isolated object that uses its radio frequency (RF) channel to read a tag and transmit its ID string over a serial port or a rudimentary network interface to a nearby PC, whereupon the PC will interact with a company's enterprise systems. Such last-generation systems are currently deployed in the form of access control systems, simple warehouse logistics systems, toll collection, and other applications. This "dumb reader" solution relies too heavily on a multitude of unreliable, insecure PCs running consumer grade operating systems that require constant human intervention. This solution cannot provide for the realization of the Auto-ID Center's vision from the standpoints of cost, scalability, maintenance cost, installation cost, and power consumption.

Instead, future RFID readers will be part of a large, distributed and dynamic system in which each reader is **responsible for the management of its local population of tags.** In this type of truly distributed system, RFID readers act as a gateway between a relatively "dumb" tag and a very "smart" distributed information system which is in turn gatewayed into enterprise software applications using a system like the **Savant** distributed database system [1]. Thus the RFID reader takes on an increasing amount of responsibility beyond that of a simple interrogator; the reader is responsible for all aspects of the management of a local population of tags that is changing dynamically to reflect the motion of tagged objects through the supply chain. The reader described in this paper has been designed to live in the context of a large network, where it provides the functionality of a specialized network gateway with an RF air interface to the tags on one side of the device, and a database server with a TCP/IP network interface on the other side, ready to be part of a distributed data aggregation and analysis system.

[1] The Savant is a distributed database system jointly developed by the Auto-ID Center and OATSystems, Inc.

Figure 1: The tag reader network architecture

THE TAG READER NETWORK ARCHITECTURE



Different applications requiring RFID tagging place vastly different demands on the RF channel of the tag/reader system. Even if the logical data structure and requirements are fixed, as in the case of systems conforming to the EPC specification, the requirements for the air interface tend to vary with the application because of the fundamental physics of antennas and radio propagation at different frequency bands. We believe that different frequency bands, for example 13.56MHz and 915MHz, and coupling technologies (near-field inductive or capacitive coupling and far-field radiation) provide different benefits and functionality trade-offs and we therefore expect that the use of at least two different frequency bands in the RFID marketplace will remain a reality for the foreseeable future. Therefore our reader is designed around the notion of simple analog band modules which can be mixed and matched to support different frequencies within the same reader.

Furthermore, the use of RFID systems in the supply chain requires technology platforms that can be standardized globally, so that tags can travel around the world and be read independently from the specific regulatory requirements in different countries. Consequently the RFID readers in this effort need to be able to read tags without regard to their frequency of operation. Additionally, since the expected lifetime of readers in supply chain management and warehouse management is as long as ten to twenty years, while the effective lifetime of a tag may be only a few days to a few weeks, readers need to be easily software-reconfigurable to support frequency bands and protocols that will become available later. Since new tags are constantly flowing into the supply chain and old tags are constantly flowing out of it, we need to allow for constant system innovation to take place on the condition that an existing reader infrastructure can support new tag technologies.

In short, we believe that "smart" RFID readers deployed in supply-chain applications should:

- operate at multiple frequency bands,
- speak Internet protocols natively,
- be part of a client-server system,
- and incorporate agent-like behavior.

The reference implementation described in this paper is the first step toward a multi-frequency, multi-protocol reader based on open standards. It is designed to communicate with a new generation of RFID tags currently being developed by the Auto-ID Center and its members based on the Electronic Product Code (EPC). The first two species of the new family of tags operate at 915MHz and 13.56MHz. Further development and production of tags at other frequency bands allocated to RFID technology worldwide are in progress. The logical data structure of these tags is made scalable across the family; at this time all of them are designed to store an EPC consisting of a 64 bit or 96 bit number. The reader functions as a translator that makes the specific air interface of the individual tag transparent to the back-end software infrastructure.

Key features of the new design include:

- frequency agility by means of modular analog signal chains,
- protocol agility by means of a DSP-based software radio design,
- standards compliant TCP/IP networking by means of a Linux-based back-end using an Ethernet network,
- low cost because most elements of the system are reused across different frequencies and protocols,
- network-driven protocol upgrades by means of firmware upgrades over an intranet or the Internet,
- interoperability between passive tags, semi-passive backscatter tags, and active tags.

By minimizing the hardware requirements for these different protocols and by implementing software modules that abstract away the differences between protocols, this Reader is superior to most other multi-band solutions in terms of hardware cost and software flexibility. It is the goal of the collaboration between ThingMagic LLC and the Auto-ID Center to make this design accessible on the same open basis as the Auto-ID Center's tag specification efforts, allowing both the end user community and the vendor community to benefit from our efforts.

2. DESIGN OVERVIEW

2.1. Design Philosophy

In designing this Reader we were guided by a small number of key principles:

1. Protocol and frequency abstraction
The physical tag technology, including carrier frequency and communication protocol, should be abstracted away from the network device talking to the reader. The reader communicates the logical properties of the EPC protocol, while hiding the specific physical transport mechanism. This requires that the most common RFID frequencies be supported by the reader so that a single reader can speak to all tags.

2. Scalability
The reader has to be designed in such a way that it scales with the amount of traffic required both on the air interface and on the network interface.

3. Ease of Deployment
The network interface has to enable easy installation, using existing networking infrastructure as much as possible. Therefore the Reader's primary interface is by means of an Ethernet based TCP/IP network.

4. Ease of Maintenance
The reader must be easily remotely maintainable by the information systems staff of an organization so that a separate maintenance staff is not needed.

5. Network Device Metaphor
The reader has to behave like a well understood network device (e.g. a router, network file server, etc) to enable large-scale deployment, configuration, and interoperability.

Guided by these basic principles, we believe that the reader and its population of tags become a natural extension to a company's general purpose Internet or intranet as we know it today (Figure 1). Note that there is no need for an intermediate PC in this architecture; all interaction with tag readers is handled on a peer-to-peer network server basis.

2.2. DSP-based Architecture

A key observation about the design of hybrid analog and digital systems (for example an RFID reader) is that the digital portion of the device can be expected to follow Moore's Law, resulting in rapidly increasing capability and decreasing cost, while the cost and functionality of the analog portion of the device can be expected to be relatively constant over time. Therefore the reader is designed around a powerful Digital Signal Processor (DSP), which handles all the modulation, demodulation and anti-collision search functionality in software. By providing most key elements of the signal chain and

related functionality digitally, the DSP provides a maximum of flexibility since the hardware can be kept constant across different protocols while the firmware is easily adapted, changed and updated.

The analog hardware of the Reader consists of a separate band module for each band, connected to the DSP system. These band modules are simple up/down converters that convert signals from the operating frequency to baseband, so that the DSP system's analog to digital converter can digitize the signal in preparation for digital demodulation.

The Reader is implemented in the form of four separate printed circuit (PC) boards which take advantage of the natural moduarity of the system:

Bamboo-DSP

The Bamboo-DSP board hosts the Bamboo Linux Server, a Digital Signal Processor (DSP), and an Analog-to-digital Converter (ADC).

13.56MHz Band Module

The 13.56MHz band module hosts the analog processing chain of the 13.56MHz signal. The board receives digital control data from the Bamboo-DSP board, connects to the 13.56MHz antenna port and provides both a thresholded digital signal as well as analog outputs to the Bamboo-DSP board for decoding. This module is capable of delivering up to 7W of RF power at a frequency adjustable in software between 13.553 – 13.567MHz.

900MHz Band Module

The 900MHz band module hosts the analog processing chain of the 900MHz signal. The board receives digital control data from the Bamboo-DSP board, connects to the 900MHz antenna port and provides two analog signals to the Bamboo-DSP board for analog-to-digital conversion and decoding. The 900MHz module is tunable in software between 902 – 928MHz and in practice is used in a frequency hopping mode, with power adjustable in software up to +28dBm.

Front Panel Module

The front-panel PC board connects to the Bamboo-DSP board. The front panel board receives user input for configuration and testing by means of four buttons and provides user feedback by means of five LEDs. Additionally the front panel module has a beeper for power on self-test (POST) codes.

2.3. Design Elements

2.3.1. Antenna Unit

The antenna unit of the Reader needs to support multiple frequency bands, with two to four orders of magnitude difference in frequency. Beyond mere differences in resonant frequencies the different bands operate in different physical regimes and hence require different coupling technology.

The current antenna unit uses a planar geometry consisting of a combination of a micropatch element for the UHF band and a coil element for the HF band. The two elements connect to the reader through two independent RF cables. It was initially expected that a single cable connection for the two bands would prove desirable, but the two bands tend to require different antenna placement since the read range at 13.56MHz is considerably less than that at 915MHz. Therefore a separate cable connection for each band is used providing maximal flexibility.

2.3.2. UHF and HF Analog Signal Chains

The analog chain of the proposed reader design is intended to be as flexible as possible. In the current implementation we provide two independent band modules for the HF and the UHF signal chains. On both boards the transmit signal is generated by means of a programmable local oscillator (PLO) module and modulated by a control line coming from the DSP/CPLD unit. The received signal is mixed to baseband using IQ demodulation resulting in two signals. Each channel is digitized in a separate 12-bit Analog-to-Digital converter (ADC) channel and handed off to the DSP for demodulation.

The number of supported frequencies can be extended by adding more hardware modules to the design.

2.3.3. Bamboo Linux Platform

The Bamboo embedded Linux server, which ThingMagic has previously internally designed and developed, is a low-cost general-purpose Linux server that consists of a Motorola 68000-based processor, the MC68EZ328, along with 8MB DRAM, 4MB Flash memory, and integrated network connectivity by means of an SMSC LAN91C96 Ethernet interface chip. Bamboo runs a port of the Linux operating system, which is a free, open-source operating system that provides highly integrated network connectivity and that allows easy application development using free tools. Bamboo has been designed as a hardware/software core that is easily customizable for specific embedded and handheld applications.

Bamboo's network stack is fast and compatible with all the standard Internet protocols, including IP, TCP, UDP, HTTP, and others. The memory architecture of Bamboo allows a fast, parallel interface to the DSP's shared memory for communication and loading of the DSP firmware. These features enable a 'division of labor' where the fast DSP handles low-level computationally intensive protocol and tag processing, while Bamboo, running at a slower pace of 16MHz, collects data when needed, initiates tag reads, and provides tag database information on the network layer.

In addition to real time data handling, Bamboo hosts a web server, which serves the HTML-based query and configuration interface of the tag reader. The query interface enables a user to issue queries using the reader query language documented below. The Web based configuration system lets the user configure the network and RF settings of the Reader.

2.3.4. DSP Module

The DSP Module is responsible for the real-time signal processing tasks in the reader. This Module receives and transmits digital signals to the Band Modules to modulate and demodulate data to and from the tag. With the expectation that the DSP will follow Moore's Law we chose a fairly inexpensive DSP chip, the TI TMS320VC5410, quoted by its manufacturer at a $10 price point in volume. This choice was made primarily on price-performance grounds; other DSPs are certainly suitable but most are more expensive than the '5410. This DSP provides reasonable performance (160MHz clock rate, typically 160MIPS) in the reader application. The computational requirements of modulation and demodulation are not too demanding given the relatively simple AM, FSK, and PSK modulations likely to be used in tag systems.

The DSP itself does not include non-volatile memory. The DSP's firmware is stored in flash memory accessible from the Bamboo Linux processor. Our design makes use of the TI DSP's Host Port Interface (HPI) interface to provide a shared memory interface in to the DSP. At boot time the DSP's firmware is loaded from the Bamboo's filesystem into the DSP through the shared memory. Therefore DSP programming occurs after Bamboo has loaded its own firmware and booted. Because of this architecture the DSP firmware can be easily upgraded in the field and only a single flash memory chip is required for the entire system, keeping the cost low.

3. READER INTERFACES

3.1. UHF EPC Air Interface

The air interface at 915MHz/868MHz is designed to be compliant with the EPC UHF protocol specification as proposed by the Auto-ID Center in collaboration with its sponsoring institutions [2].

[2] The authors thank Alien Technology and Rafsec Oy for their support and cooperation during the development of this specification.

The goal of the UHF EPC interface is to provide an open standard interface that lets different manufacturers build devices that understand each other. While the protocol specifications itself are open, the specific physical implementation and manufacturing technology are left to the individual manufacturer. Hence contributing companies retain a competitive edge by developing proprietary manufacturing processes and device implementations.

The version of the UHF EPC protocol currently running on the Reader is specified in the document "Operational Specification for a Very Low Cost (VLC) Radio Frequency Identification (RFID) System. Part I. Class 1 Devices. Version 9.1" (1). The 915MHz EPC air interface has been designed to comply with Part 15 FCC regulations. A full EMC evaluation and Part 15 certification has not been attempted on the prototype hardware.

3.2. HF EPC Air Interface

The air interface at 13.56MHz is designed to be compliant with the EPC HF protocol specification as proposed by the Auto-ID Center in collaboration with its sponsoring institutions [3].

[3] The authors would like to thank Philips Semiconductors, Rafsec Oy, and Peter Cole for their support and cooperation during the development of this specification.

While the HF tag protocol is designed to largely the same functional requirements as the UHF design, the different physical boundary conditions and regulatory requirements impose a different air interface and logical level protocols. For example, the implementation of the anti-collision algorithm is guided by the available bandwidth for reader-to-tag and tag-to-reader communication. Since these parameters are significantly different for the two bands, a very different anti-collision algorithm was selected for the HF specification.

The version of the HF EPC protocol currently running on the Reader is specified in the document "Revised Draft Specification for an HF EPC Label" (2). The 13.56MHz EPC air interface has been designed to comply with European electromagnetic emission regulations (CE regulations) for the 13.56MHz band. A full EMC evaluation and Part 15 certification has not been attempted on the prototype hardware.

3.3. Reader Query Protocol

To enable a scalable client-server infrastructure between back-end software and the reader, an open and scalable protocol, SQL, was adapted to run across the TCP/IP interface of the tag reader's tag database server. The protocol is used in connection with the Savant hierarchical database software, which has been designed to connect to various different EPC tag readers.

The interface between the reader and the network is defined by a tag database server that speaks a variant of the extensible Structured Query Language commonly used in enterprise database systems. This language is derived from ANSI standards documents X3.135-1989 and X3.168-1989. The Reader

SQL is an extension of SQL specifically designed to access a variety of tags with different frequencies of operation and protocols. The SQL server communicates between the tag database stored in the DSP/ Bamboo shared memory and a host on a network. The host can make a structured query to retrieve arbitrary subsets of the tags in the field based on a number of criteria such as the ID of the tag, the protocol, the antenna and more. The server will request tags and return only those that match the structured query. The server can operate in a poll mode where tags are returned within a specified timeout or in streaming mode, where the tag database is reported at any integer number of millisecond intervals. The tag database can also be queried in a human readable format such as standard telnet (specified in RFC 0854).

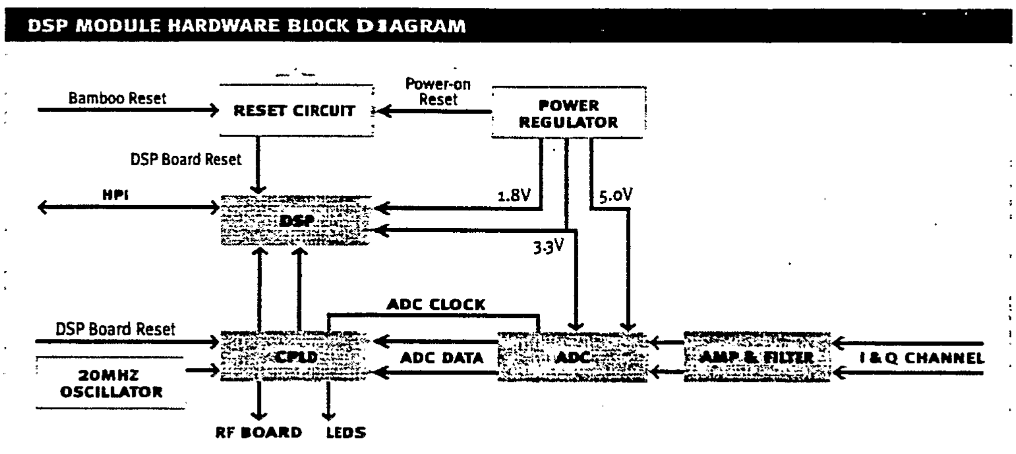
The query protocol is documented in (3).

4. HARDWARE DESIGN

4.1. DSP Board Design

The DSP Module as shown in Fig.2 consists of three main circuit blocks:

Figure 2: DSP module – hardware block diagram



1. **DSP (Digital Signal Processor) block** including a TMS320VC5410 DSP from Texas Instruments and its associated support circuitry such as clock oscillator and power-on reset circuit.

2. **CPLD (Complex Programmable Logic Device)** using the XC95144XL CPLD from Xilinx Inc.

3. **Analog circuit block** using the ADS2807 12-bit ADC from Texas Instruments and an amplifier/filter circuit using OPA2681 high speed operational amplifiers.

The DSP system uses the TMS320VC5410A DSP from Texas Instruments operating at 160 MHz. This chip includes 64 Kwords of on-chip RAM which is used for both program and data storage. Its core voltage is 1.8 Volts while the I/O supply voltage is 3.3 V. The DSP is configured in "Microcontroller Mode" by tying the MP/MC pin to ground, allowing it to boot from on board RAM. The DSP interfaces to Bamboo through its Host Port Interface (HPI). The processor can be reset either manually using a switch, by power-cycling,

or under the software control of the Bamboo. Following a reset, the DSP waits for the Bamboo to download the DSP's operating firmware into its on-chip memory through the HPI. The HPI is also used for transferring run time data between Bamboo and the DSP by means of a shared memory interface. Details of the data transfer are explained in the software section.

The DSP interfaces to a CPLD chip (XC95144XL from Xilinx Inc.) via the DSP's two Multi-channel Buffered Serial Ports (McBSP). The McBSP configuration is tabulated in Table 1. The CPLD interfaces with the ADC using a generic parallel port interface. One of the functions of the CPLD is to latch two streams of 12 bit ADC data into its internal registers and serially shift out this data on McBSP0 and McBSP1 to the DSP.

Table 1: DSP – McBSP Configuration

MCBSP	DIRECTION (RELATIVE TO DSP)	BIT RATE	DATA
0	Tx	24 Mbps	Register Settings for CPLD
0	Rx	24 Mbps	I channel ADC data
1	Tx	1 Mbps	Bit sequence for RF transmission
1	Rx	24 Mbps	Q channel for ADC data

The CPLD has various internal 8bit registers to which the DSP can write using the McBSP. The register addresss and functions are tabulated in Table 2. The DSP uses the McBSP0 Tx line to write into the CPLD registers. The McBSP data is based on a 12 bit mixed address-data format; the first 4 bits designate the address of the CPLD register (LSB first), while the remaining 8 bits designate the data to be latched into the CPLD register (LSB first).

Table 2: CPLD register addresses and function

REGISTER ADDRESS	REGISTER NAME	DESCRIPTION
0	RESERVE_REG	This is reserved
1	VERSION_REG	This stores version of the CPLD code
2	ADC_DIV_REG	Division factor for ADC clock (CPLD clock is divided by this factor and given to ADC)
3	RF_GIO1_REG	Digital I/O lines for RF board (GPIO lines 0..7)
4	RF_GIO2_REG	Digital I/O lines for RF board (GPIO lines 8..15)
5	LED_REG_REG	LED state. (bit0 = LED1, bit1 = LED2, bit2 = LED3)
6	SWRESET_REG	This is reserved
7	DIAG_REG	When LSB in this register is set, ADC output is not given to DSP, instead a repetitive test pattern is generated internal to CPLD and given to DSP.
8	DDS_REG0	This is reserved
9	DDS_REG1	This is reserved
10	DDS_REG2	This is reserved
11	DDS_REG3	This is reserved
12	DDS_REG4	This is reserved
13	MBSP_PASS_REG	When a bit 0..7 is set corresponding GPIO line 8..15 reflects logic state of McBSP Tx1 line.

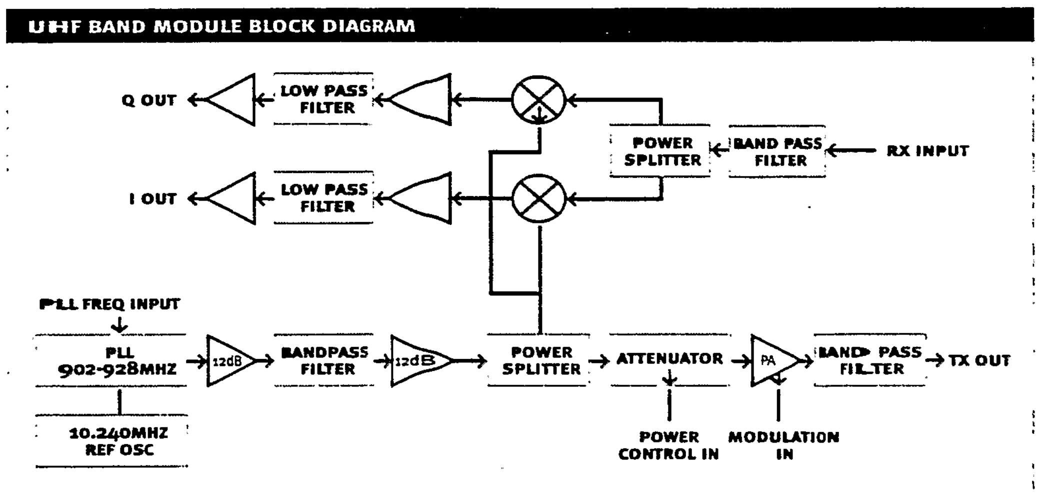
Internal timing of the CPLD is driven by a 20Mhz crystal oscillator. This 20Mhz frequency is divided and supplied to the ADC for sampling the analog data. The division factor can be programmed by the DSP by writing to one of the registers of the CPLD. The CPLD also includes a register which controls the state of four system LEDs on the front panel.

The DSP board contains a small block of analog circuitry for conditioning two incoming analog signals prior to conversion in the ADC. The input signals are filtered and amplified by a factor of two. An offset of 2.5V is added to the signals to match the dynamic range of the ADC. The ADC uses an analog power supply at 5V with the dynamic range of the input signal set to 1.5V to 3.5V. The signals are low-pass filtered with a cut-off frequency of 450kHz, and are sampled at 1.67MHz.

4.2. UHF Band Module

The UHF band module is a channelized 902/928MHz-to-baseband downconverter designed for frequency hopping operation under the FCC's Part 15.247 rules. These rules specify that a maximum output power of 1W may be used in a frequency hopping system using at least 50 channels, with maximum dwell time of 400mS at any given frequency. The band module was therefore subject to to the limitations of PLL lock time and receiver T-R recovery time. A conscious trade-off was made between channel utilization and cost; a single synthesizer design was chosen because of its lower cost even though the synthesizer lock time would result in "dead time" in which the reader field would be off during channel transitions.

Figure 4: UHF Band Module – Block Diagram



4.2.1. Local Oscillator

The operating frequency is generated by a phase locked loop synthesizer module (Z-Comm Inc PSN0930A), integrating a VCO and a National Semiconductor LMX2316 PLL IC. This inexpensive module generates +3dBm output power with phase noise specified at −100dBc/Hz at 10KHz. Significant harmonic energy is present at the VCO output port. In order to increase VCO load isolation, a 6dB attenuator pad is used between the VCO and the first MMIC amplifier (a Mini-Circuits ERA-3SM). This amplifier is biased from the +12V supply with a standard L/R bias network. The amplifier's output power is approximately +8dBm at this point. The amplifier's output is filtered by a two-pole ceramic monoblock bandpass filter centered at 915MHz to remove the second harmonic and other spurious outputs. A second MMIC amplifier and 3dB power splitter split this local oscillator signal into two paths, one for transmit and one for receive.

4.2.2. Transmit Chain

The transmit signal comprises a Hittite Microwave 3-bit digitally controlled step attenuator (for power control) and an RF Micro Devices GSM/AMPS GaAs power amplifier IC, followed by a second ceramic monoblock bandpass filter for harmonic and spurious output suppression. This chain is capable of delivering up to +28dBm at 915MHz. The transmitter can be amplitude modulated by means of the power amplifier's power control input; this is accomplished under digital control from the 900MHz chain's CPLD. While closed loop power control was initially designed into past prototypes, the difficulty of achieving sufficient power control bandwidth at reasonable cost and complexity led to the present open loop design, which has been found to be sufficient for this application.

4.2.3. Receive Chain

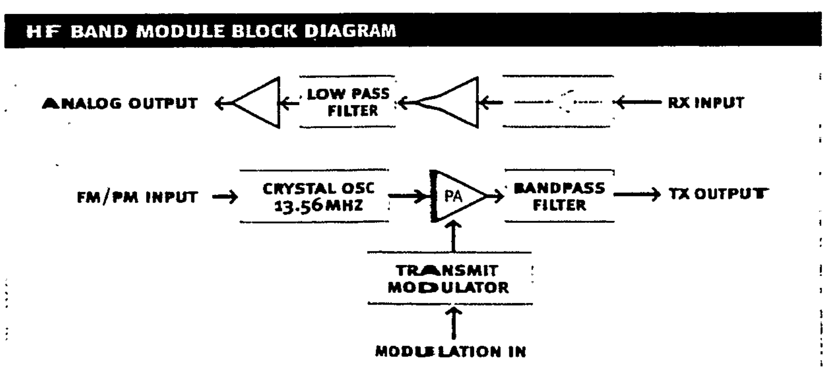
The majority of the receive chain is implemented in software on the DSP. Therefore the analog receive section is very simple. The incoming RF signal is filtered by a ceramic bandpass filter and split into two signal paths for quadrature (IQ) demodulation. This signal is fed to two Mini-Circuits double-balanced mixers; their local oscillator signals are generated by splitting and phase delaying the receive LO path to generate a 90 degree lag in the Q path. No front end RF preamplifier is used because large signal handling capability is more important than receive-noise figure.

The I and Q channel outputs are amplified and filtered by a 4-pole Bessel antialiasing filter with its cutoff frequency at 450KHz. These two signals are then applied to the analog to digital converter on the Bamboo-DSP board. Further signal processing is accomplished digitally; this is the most general approach possible.

4.3. HF Band Module

The HF band module is designed to receive inductively coupled, load modulated signals from an EPC compliant label. It is capable of generating a variable transmit power of up to 7W at a software controlled frequency between 13.553–13.567MHz. The receive section is similar to the UHF band module in that the majority of the signal processing tasks are handled in software on the DSP.

Figure 5: HF Band Module – Block Diagram



4.3.1. Local oscillator

Since the 13.56MHz band is only 14KHz wide, a variable crystal oscillator can be employed. In this design a varactor "pulls" the crystal oscillator; the nominal crystal frequency is 13.560MHz, and at the extrema of the tuning range about 14KHz of tuning range can be achieved under the control of a 12 bit DAC. This capability is useful mainly for output spectrum control during transmit modulation, if desired.

4.3.2. Transmit Amplifier

The transmit power amplifier is a switched mode design operating in a nearly class E mode. This amplifier is designed around an inexpensive logic-level drive MOSFET, the IRL510. Gate drive is supplied by an HCMOS logic IC driving a pair of high speed, high gain bipolar transistors. The gate is driven at 50% duty cycle, while transmit power is modulated by drain voltage derived from a linear amplifier driven by another section of the 12 bit DAC. Thus the transmitter power may be adjusted dynamically and separately for nominal and dip modulation intervals. The output is filtered by the normal series-resonant network and is matched from an internal 12.5 Ohm target load impedance to the 50 Ohm output impedance by means of the same network.

4.3.3. Receive Chain

The 13.56MHz receive chain is based on the standard voltage doubling AM detector circuit, followed by a 13.56MHz trap circuit. An antialiasing filter identical to that used at 915MHz is used before amplification and analog-to-digital conversion on the Bamboo-DSP board. In addition to this output, an otherwise unused opamp section is employed as a comparator to provide a thresholded digital output to the CPLD for testing bit-level demodulation options.

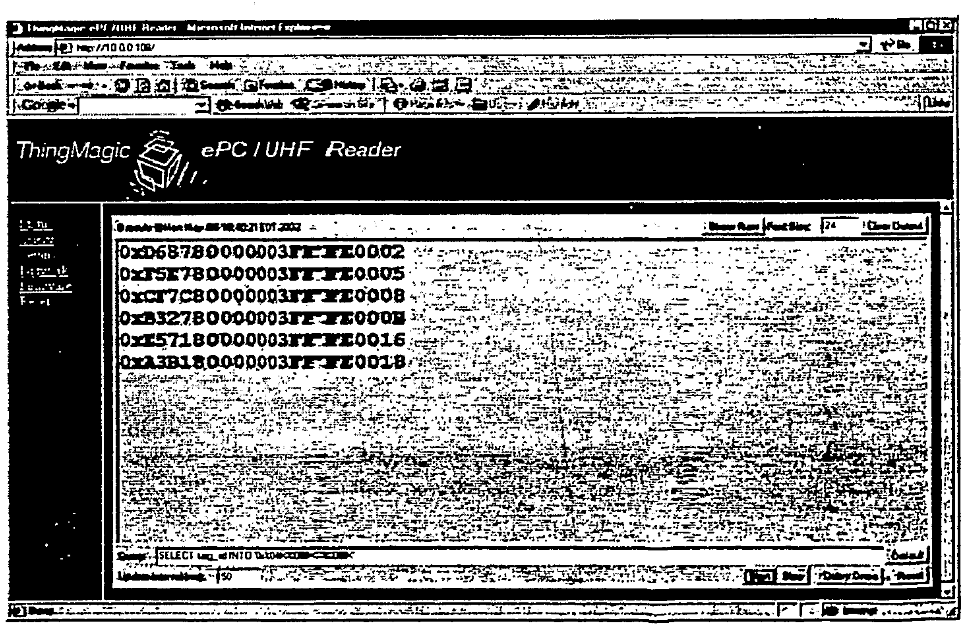
5. SOFTWARE DESIGN

5.1. General Software Architecture

5.1.1. Query Processing Chain

A tag read is exclusively initiated by a client software or user connected to a TCP/IP network. The query client is either embodied in a browser-based Java query interface hosted by the reader (Figures 6 and 7) or it is itself part of a higher-level data handling infrastructure like the Savant. However, it can also be queried simply by a user manually typing requests through a telnet program. The protocol is an SQL-like language carried over a standard internet TCP stream connection (see below).

Figure 6: Java Reader interface – Query Page: Six aggregated EPC numbers are displayed in the browser window.



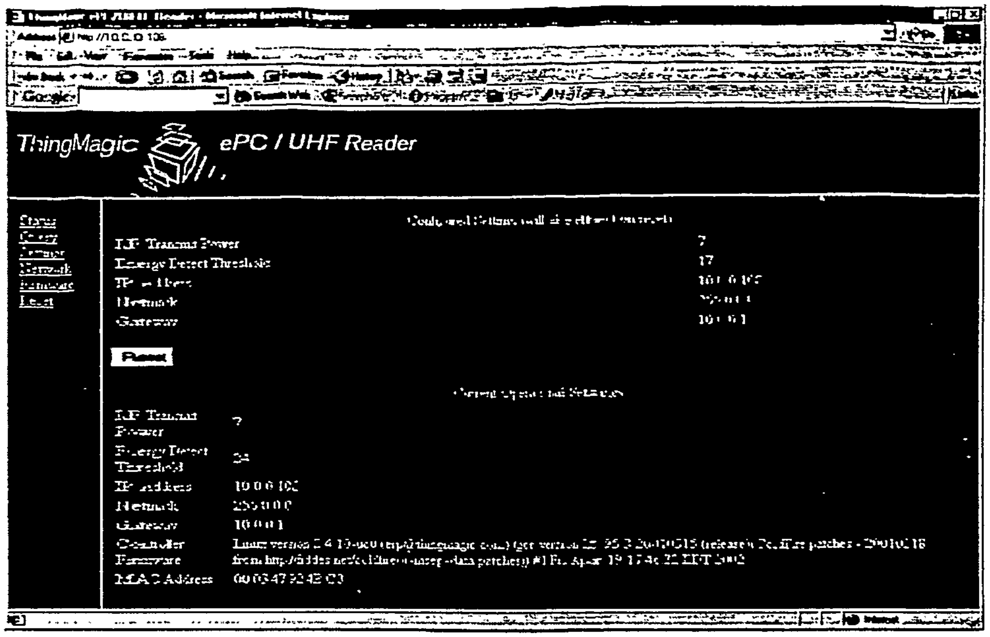


Figure 7: Java Reader interface – Configuration Page: the interface to select the network configuration, reset the device to the factory settings, or select the RF properties.

The query server resides on Bamboo, a general-purpose, Linux-based embedded processor. It receives SQL requests from the other end of the TCP connection and interprets them into a series of actions for the DSP. Once the result is received from the DSP, the SQL server forwards the results to the network client. Communication between Bamboo and the DSP occurs through a shared-memory mechanism which is physically connected through the DSP's HPI port.

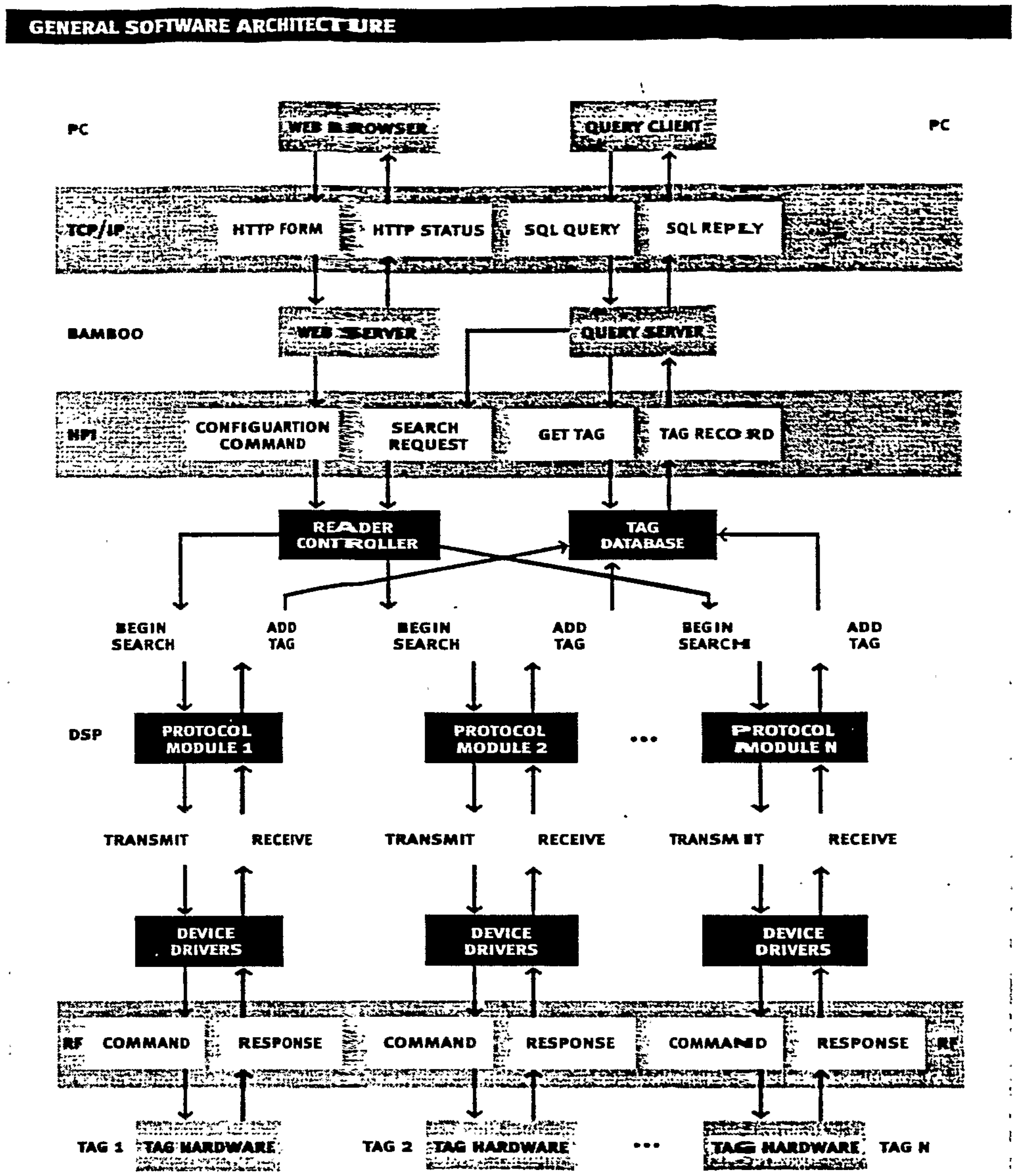
The query server instructs the DSP to run a structured tag search based on the parameters contained in the SQL query. Within the DSP, the top-level control software requests a search from a protocol module, which encapsulates the particulars of a tag protocol. The protocol module communicates with the device drivers, which manipulate the DSP hardware to send and receive radio signals to and from the tag.

As tag responses are received, the protocol module stores them in a tag database which is shared between all the protocol modules running on the tag reader. After completion of the search, the SQL server reads the contents from the tag database. The tag records are collated and packaged into a SQL reply to send back to the client.

Figure 3 summarizes the software architecture of the Reader.

Published June 1, 2002. Distribution restricted to Sponsors until September 1, 2002.

Figure 3: General software architecture – block diagram



5.1.2. Multi-Protocol Capability

Because of the functional abstraction of the reader's software system, changes to the system to support additional protocols are limited to the protocol modules and their device drivers. Adding support for more protocols involves little change at the higher levels of the system. At the client level, users or software infrastructure are given additional options for new protocols, but the network interface remains unchanged. Similarly, at the Bamboo level, new protocol options are processed but the basic software structure is not changed.

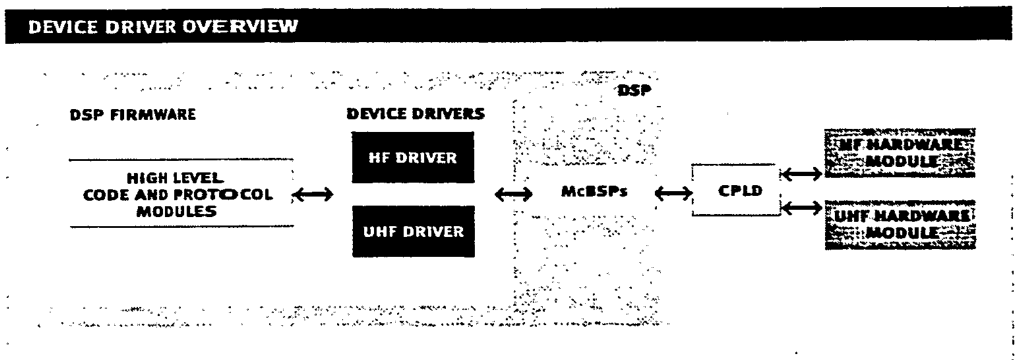
The tag database associates a particular protocol with a particular tag record through a protocol ID field (a "magic number"). The Query Server communicates the protocol ID of a specific tag to the client if so requested.

5.1.3. Reader Configuration
Bamboo hosts a Web server which provides an interface to the Reader configuration settings. Using standard HTML pages and form submissions, the web server reports status and allows configuration of parameters, including power level and network configuration settings such as the IP address.

5.2. Device Drivers

The interface from the DSP firmware to the hardware is abstracted into a set of device drivers. As shown in Figure 8, the device drivers separate the high-level firmware and protocol modules from the low-level hardware interfaces. Device drivers are provided for the transmit (TX) and receive (RX) chains of each RF module, as well as for other hardware functions such as the LED front-panel display.

Figure 8: Device Driver Overview: The device driver are a set of software modules that abstract the hardware interface for the high-level DSP code and protocol modules



The device driver code translates the function calls to the device into hardware operations to perform the desired function. The device drivers abstract the hardware interface both by managing on-chip DSP peripherals (e.g., serial ports and DMA controllers) and low-level details of the external hardware devices. Details of the hardware interfaces are discussed in Section 4. The RF device drivers are designed to provide access to the hardware in a protocol-independent manner in order to allow all protocol modules supported by the hardware to operate on a small total number of device drivers. The device driver application program interface (API) consists of a set of C-callable functions for writing data to or reading data from the device or for configuring device parameters. This API mimics the POSIX file I/O interface, using `write`, `read`, and `ioctl` functions for these procedures. A device driver is made active by calling `open` and released by calling `close`.

The `ioctl` call provides an interface to device-specific configuration functions. Table 3 shows the list of configuration functions for the UHF TX and RX devices as an example.

The precise meaning of writing to or reading from a device depends on the nature of the device, and in some cases may be an illegal operation (e.g., writing to an RX device or reading from a TX device). Some devices (e.g., the LED front-panel display device) provide neither a `write` nor a `read` function. These devices are entirely controlled by `ioctl` functions.

Published June 1, 2002. Distribution restricted to Sponsors until September 1, 2002.

Table 3: Configuration functions for UHF TX and RX

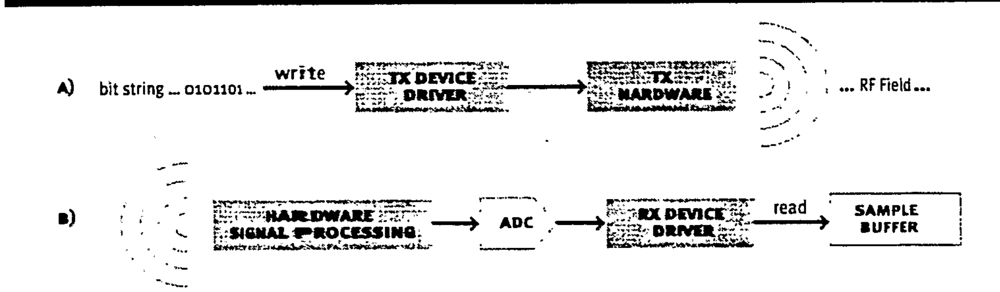
CONFIGURATION FUNCTIONS FOR UHF TX AND RX

IOCTL FUNCTION	EFFECT
[illegible]	
set_passthru	When passthru is set to 1, bits written to the device are transmitted over RF as on-off keyed chips at the chip rate set by the set_rate ioctl function. When set to 0, the RF output is held steadily on or off as specified by a call to set_RF_state and writes to the device are ignored.
set_rate	Sets RF chip rate for bits written to the device.
set_RF_state	Sets RF field to be on or off. The state is only used when passthru is set to 0.
freq_hop	Yields for a frequency hop.
set_RF_power	Sets RF output field strength.
[illegible]	
IOCTL FUNCTION	**EFFECT**
set_rate	Sets the sampling rate used to collect samples for a device read operation.

Writing to a TX driver typically causes data to be modulated over the output field. Reading from the RX driver fills an input buffer with samples from an ADC. Generally, these samples will represent a partially-demodulated data stream requiring further signal processing. The operations are illustrated in Figure 9.

Figure 9: Typical RF device driver interfaces are through the (a) `write` and (b) `read` operations. These calls use the hardware to transmit and receive data over the RF channel as shown

TYPICAL RF DEVICE DRIVER INTERFACE



Because the various devices share hardware resources (e.g., both the HF and UHF TX devices send data over the same hardware serial port), some form of resource management is required. In this system the high-level firmware manages the resources to avoid conflicts. In general, this is accomplished by only keeping one device driver active at a time. For situations where multiple device drivers must be active simultaneously (e.g., for timing-critical coordination of transmission and reception), safe combinations of device driver function calls are specified.

5.3. UHF Software Module

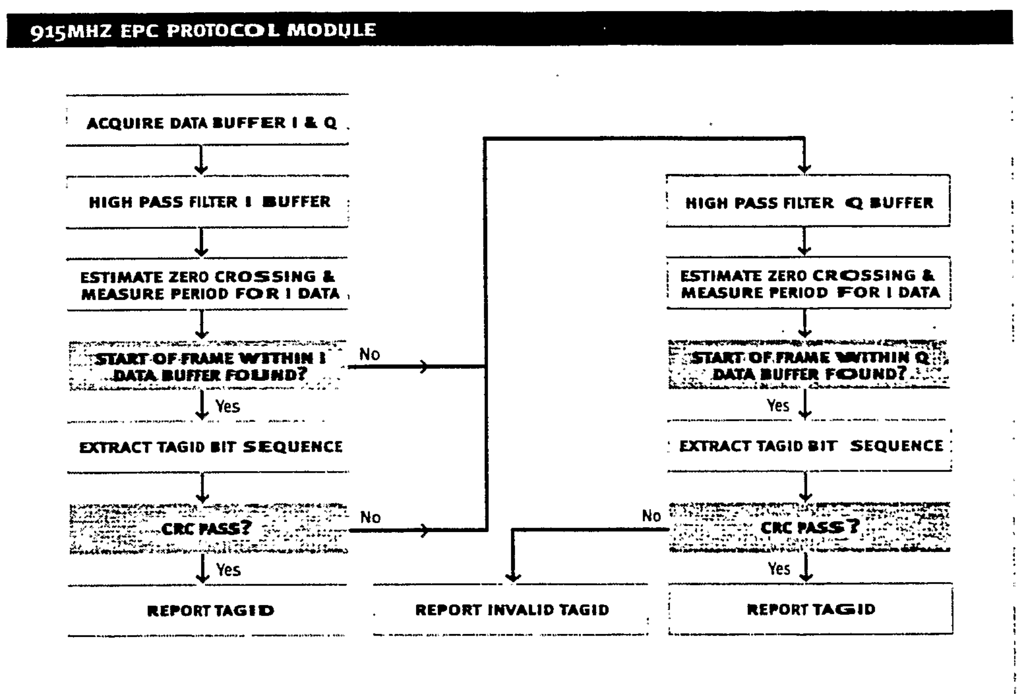
5.3.1. Command Structure

The UHF software module is implemented in its entirety on the DSP. It supports the following calls:

1. `AC_search_start` (anti-collision_search_start) initiates the anti-collision search. Any tags found in the field are reported by registering them in the tag data base. The data base is queried by Bamboo.
2. `AC_search_stop` halts the AC search initiated by the `AC_start_command`.
3. `AC_search_step` steps through the AC search one tag query command at a time.
4. `ping` makes the DSP issue a Ping 0 or Ping 1 command to which tags in the field can be expected to respond.
5. `scroll_start` makes the DSP issue Global scroll continuously. Any tags found are reported to the tag database.
6. `scroll_stop` stops the scroll initiated by `scroll_start` command.
7. `set_ping_threshold` sets the power threshold for detection of tag response to ping command.

The details of various commands and tag responses are defined in detail in (1).

Figure 10: 915MHz EPC module – receive signal, signal processing flowchart



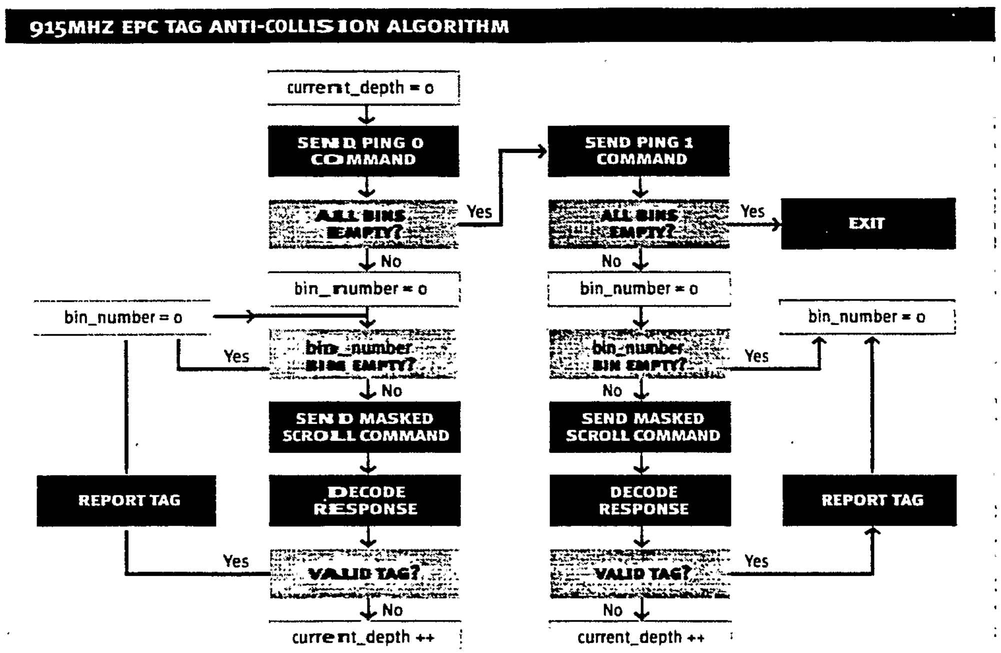
5.3.2. Anti-Collision Algorithm

The UHF EPC tags respond to three commands: `Ping`, `Masked Scroll` and `Global Scroll`. A `Global Scroll` will make all the tags in the field respond at the same time, causing a collision if there is more than one. Hence it is necessary to implement an anti-collision search (AC search) which makes only certain tags respond at a time based on a systematic use of `Ping` and `Masked Scroll` commands.

The AC algorithm for decoding multiple tags in the field is implemented using a combination of `Ping` and `Masked Scroll` commands. The search follows an octal tree in a depth first approach. Figure 11 shows the flow chart for the AC search for the variable `current_depth` set to zero. This variable indicates the length of the bits in the Tag ID being queried and hence the current depth of the search tree. `current_depth` of zero indicates bits 2 to 4 are being queried. A `current_depth` of 1 indicates bits 5 to 7 are being queried and so on.

The AC search starts by sending out a `Ping 0` command. In response to a `Ping 0` command, tags with a least significant bit of zero will respond. The response is received in one of the eight bins. The bin number in which the tag response is received indicates the next three bits of the tag ID. For example, if the `Ping 0` command were sent and a response were received in Bin 3, then the first four bits of the tag ID of the tags which respond: `0 011`. A `Masked Scroll` command is then issued for all the bins in which tag responses were recorded.

Figure 11: 915MHz EPC tag – anti-collision flowchart



The `Masked Scroll` command makes use of the tag ID bits determined so far in the search. The tag responds with its entire tag ID. In case the decoding of the tag ID fails, it is concluded that more than one tag responded and it is necessary to differentiate the tag IDs further by sending out `Ping` commands with more bits. In this case the `current_depth` variable is incremented. If a valid tag ID is decoded, the tag ID is put into the database and the remaining bins that contain a `Ping` response are probed by sending a `Masked Scroll` command.

When the `current_depth` variable is incremented, a `Ping` command is sent with three additional bits in the bit mask. This process is repeated until there are no tag responses at a given `current_depth` or till `current_depth` reaches a maximum value based on the maximum number of bits in a tag ID.

After finishing the `Ping 0` tree, a `Ping 1` command is sent and the `Ping 1` tree is searched in the same fashion as the `Ping 0` tree.

5.3.3. Signal Flow and Demodulation

Each command sent to the tag has a unique command bit code which is detailed in (1). The DSP formats the bit sequence based on the command code and command parameters to be transmitted. The bit sequence includes appropriate CRC values required by the tag to validate the command. The composed bit sequence is transmitted from the DSP to the CPLD via the DMA and McBSP. The CPLD in turn lets the data pass through to the modulation input of the RF board.

In the return channel a down-converted RF signal is digitized by the ADC and given to the DSP through a CPLD. The data is of 12 bit dynamic range. The DSP filters the signal and then processes the data further to extract the data bits.

5.3.4. Scroll Processing

A tag responds to a `Scroll` command by sending out its Tag ID encoded in sidebands of the carrier frequency. Due to variation of the tag clock the bit period of the tag to reader signal can vary greatly. The bit period may also drift while the Tag is transmitting its response. The actual bit period is determined by the DSP by searching for a known preamble bit pattern transmitted by the Tag. Once this bit period is determined, the Tag ID is decoded by fitting the received signal to the pattern expected for bit one or bit zero. During this process the bit-period estimate is constantly being updated to account for the drift in the bit period. The signal processing steps are detailed in Figure 10.

Once the required number of bits is received the Tag ID is validated by checking the CRC. Once the CRC check is passed the Tag ID is reported to the database.

5.3.5. Ping Processing

A tag responds to a ping command by sending 8 bits of data in the appropriate `Ping` Bin (Bins 1 to 8). The DSP software module evaluates the energy in each Bin by comparing it to a reference Bin. If the power of the signal is more than an adjustable threshold times the power in the response-free reference signal it is concluded that at least one tag is present in the Bin.

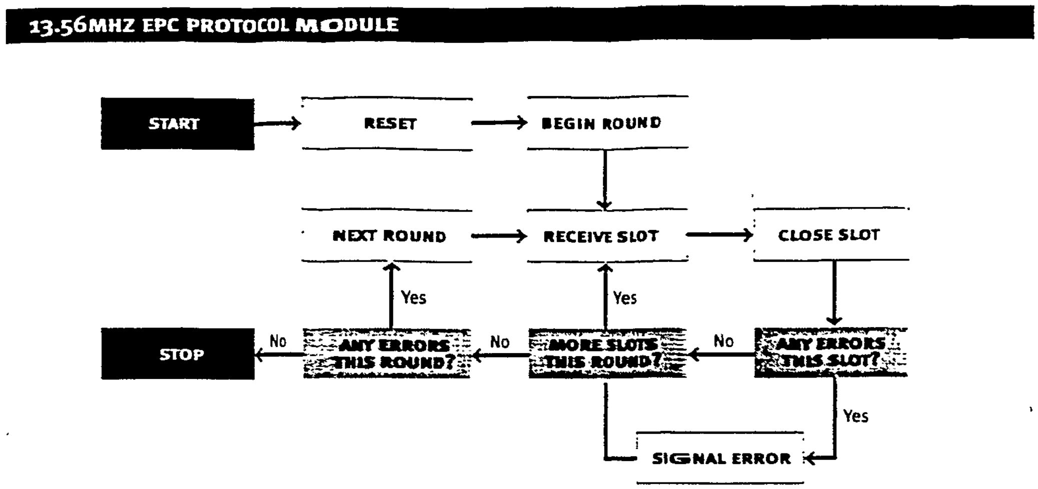
5.4. HF Software Module

Unlike the EPC UHF protocol, the EPC HF protocol and its anti-collision scheme is based on the idea of pseudo-random slotting, i.e. tags respond at different times thus avoiding collision. The basic transaction in the EPC HF protocol is a "slot" which, simply put, is a time slot in which a single tag is expected to reply. Slots are gathered into groups called "rounds," each of which has a fixed number of slots, declared at the beginning of the round. A tag search consists of a series of rounds, one right after another, until all available tags have been heard from.

Before a search cycle begins, a `Reset` is issued to put all tags into a known starting state. The search is then started with a `Begin Round` command.

The inner loop of the search process processes a single slot. First, the Reader listens for the duration of the slot and attempts to decode a tag response from the received signal. After this processing is done, it closes the slot by sending a `Close Slot` signal.

Figure 12: 13.56MHz EPC tag – reader protocol module flowchart



In addition, an error signal is sent if the Reader believes that the previous slot contained a tag response but was unable to decode it properly. This error signal informs the tag that its response was not successfully received and that it should repeat its response later (during the next round.)

The inner loop repeats for every slot in the current round (a number which was predetermined at the beginning of the round, and should ideally be chosen to minimize the chance of collisions between tags while also minimizing the number of unused slots.)

When the round is completed, the Reader decides whether or not another round is necessary based on whether or not there were any collisions (decode errors) during the round. A collision implies that there is still at least one tag that is responding, but has not been successfully heard. In this case, a new round is initiated with the next round command, and the cycle begins again.

6. CONCLUSIONS

This paper puts into context and motivates the concept of a multi-frequency EPC tag reader. It further summarizes the basic design principles and choices for the reference implementation of such a reader, and finally explains that implementation in detail. In addition to this white paper, a set of hardware schematics and firmware source code will be made available under license by the Auto-ID Center. These documents in combination with this paper constitute the EPC Reader Reference Design, which will enable a skilled engineer to reproduce the design and manufacture a working reader, or to use this Reference Design as a starting point for another EPC reader design.

A systematic performance evaluation of the Reader will be undertaken over the coming months. We will examine read range and read pattern with varying antenna design and frequencies, read-rate variation in different geometries, throughput of the anti-collision search, and reliability of reads under real-world conditions.

The dual-band reader offers an outstanding opportunity to directly and simultaneously compare the performance of HF versus UHF RFID technology. With the back-end software interface and the digital

reader infrastructure remaining constant, a comparison can be made between the true performance differences due to the analog front-end circuitry and air-interfaces. It is the author's belief that such testing will reaffirm the need for multiple frequency bands in supply chain RFID deployment and hence the need for multi-band RFID readers.

7. ACKNOWLEDGEMENTS

The authors would like to thank Kevin Ashton, Sanjay Sarma, Peter Cole, Dan Engels, Silvio Albano, the Auto-ID Center, and the Auto-ID Center's Sponsor Community for making this work possible.

8. REFERENCES

1. **Auto-ID Center. Operational Specification for a Very Low Cost (VLC) Radio Frequency Identification (RFID) System. Part I. Class 1 Devices.**
   Version 9.1., 2002.

2. **Auto-ID Center. Revised Draft Specification for an HF EPC Label,**
   March 8, 2002.

3. **ThingMagic LLC. Reader Query Protocol.**
   Rev. 1.2, April 2002. To be published by the Auto-ID Center.

SHARP

APPENDIX C

GP1S36

GP1S36

Photointerrupter for Detecting Tilt Direction

■ Features

1. Subminiature (4.0×4.2×3.8mm)
   (with built-in super compact ball for detecting tilt direction)
2. 2-phase output type
3. Able to detect the tilt direction of both side (±90°) by the position of rolling ball.
4. High reliability due to non-contact structure

■ Applications

1. Digital cameras
2. Camcoders

■ Absolute Maximum Ratings

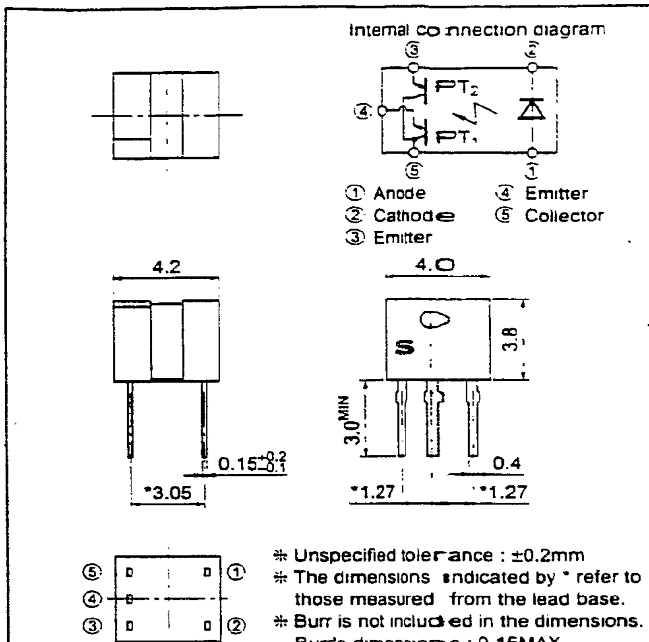
(Ta=25°C)

	Parameter	Symbol	Rating	Unit
Input	Forward current	I_F	50	mA
	Reverse voltage	V_R	6	V
	Power dissipation	P	75	mW
Output	Collector-emitter voltage	V_{CE_1O} / V_{CE_2O}	35	V
	Emitter-collector voltage	V_{E_1CO} / V_{E_2CO}	6	V
	Collector current	I_C	20	mA
	Collector Power dissipation	P_C	75	mW
	Total power dissipation	P_{tot}	100	mW
	Operating temperature	T_{opr}	−25 to +85	°C
	Storage temperature	T_{stg}	−40 to +100	°C
	*1 Soldering temperature 1	T_{sol}	260	°C
	*2 Soldering temperature 2	T_{sol}	320	°C

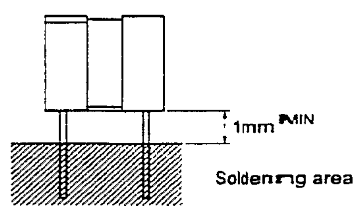
*1 For MAX. 5s
*2 For MAX. 2s at the position of 0.8mm from the bottomface of resin package by hand soldering.

■ Outline Dimensions

(Unit : mm)



※ Unspecified tolerance : ±0.2mm
※ The dimensions indicated by * refer to those measured from the lead base.
※ Burr is not included in the dimensions. Burr's dimensions : 0.15MAX.



SHARP **GP1S36**

■ Electro-optical Characteristics

(Ta=25°C)

Parameter			Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input	Forward voltage		V_F	I_F=20mA	–	1.2	1.4	V
	Reverse current		I_R	V_R=3V	–	–	10	μA
*3 Output	Collector dark current		I_{CEO}	V_{CE}=20V	–	–	100	nA
*3 Coupling Characteristics	Collector current		I_C	V_{CE}=5V, I_F=5mA	60	–	360	μA
	*4 Leak current		I_{LEAK}	V_{CE}=5V, I_F=5mA			15	μA
	Response time	Rise time	t_r	V_{CE}=5V, I_C=100μA	–	50	150	μs
		Fall time	t_f	R_L=1 000Ω	–	50	150	μs
	Collector-emitter saturation voltage		$V_{CE(sat)}$	I_F=10mA, I_C=60μA	–	–	0.4	V

*3 Output and coupling characteristics are common to the both phototransistors.
*4 Characteristics except leak current is measured at θ=0°, ϕ=0°.
Leak current is the output current of transistor when θ=±90°, ϕ=0° and IC=OFF.

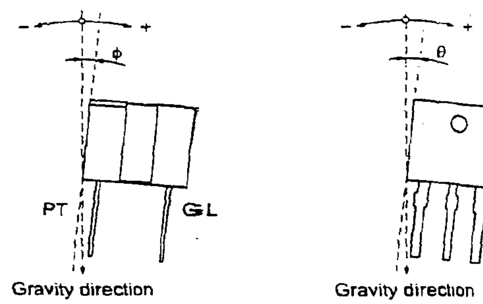
■ Detecting Angle Characteristics

θ	-90°	↔	-75°	↔	-15°	↔	+15°	↔	+75°	↔	+90°
I_{C1}				ON				*5		OFF	
I_{C2}		OFF		*5				ON			

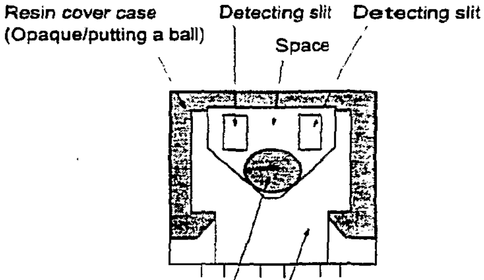
⁜ Conditions : I_F=5mA, V_{CC}=5V, ϕ<=±5°
*5 Indefinite

I_{C1} : Output current of phototransistors PT_1
I_{C2} : Output current of phototransistors PT_2
θ : Device condition : Refer to the figure
ϕ : Device condition : Refer to the figure
ON :Output current of phototransistors : 60μA or more
OFF : Output current of phototransistors : 15μA or less
⁜ Output current of ON/OFF is output when device is at a standstill

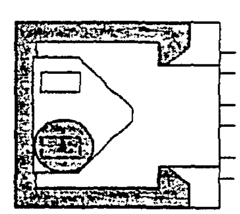
Device state diagram



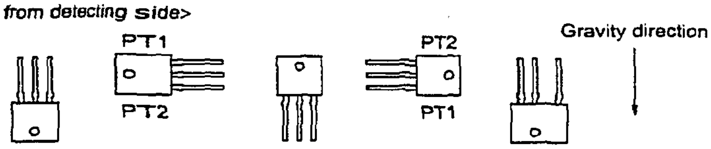
■ Supplement



<90°rotation>



<Viewing from detecting side>



PT1 output	Indefinite	(ON)	(ON)	(OFF)	Indefinite
PT2 output	Indefinite	(OFF)	(ON)	(ON)	Indefinite

PT : Detecting
PT : Opaque
PT : Indefinite

Fig.1 Forward Current vs. Ambient Temperature

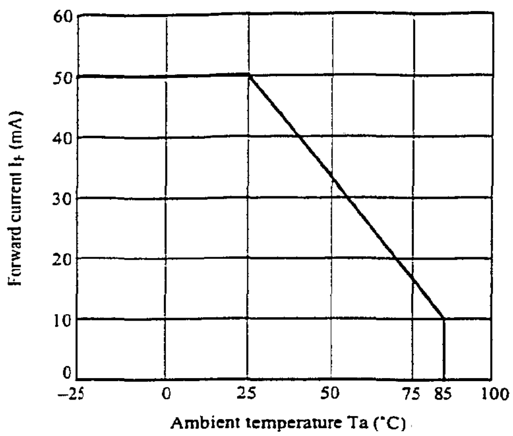


Fig.2 Power Dissipation vs. Ambient Temperature

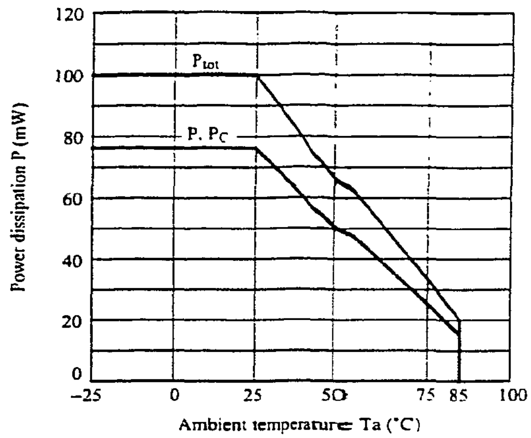


Fig.3 Forward Current vs. Forward Voltage

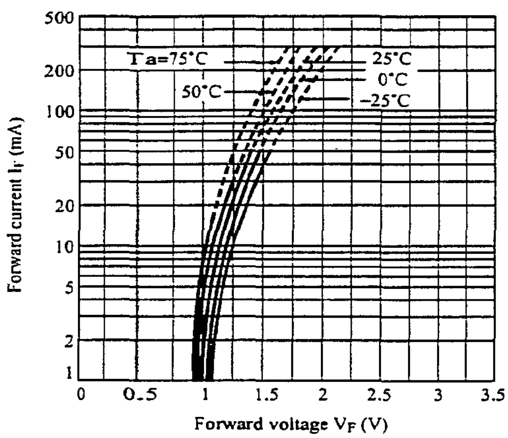


Fig.4 Collector Current vs. Forward Current

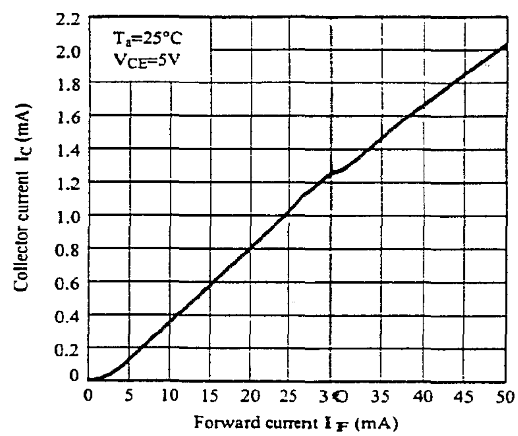


Fig.5 Collector Current vs. Collector-emitter Voltage

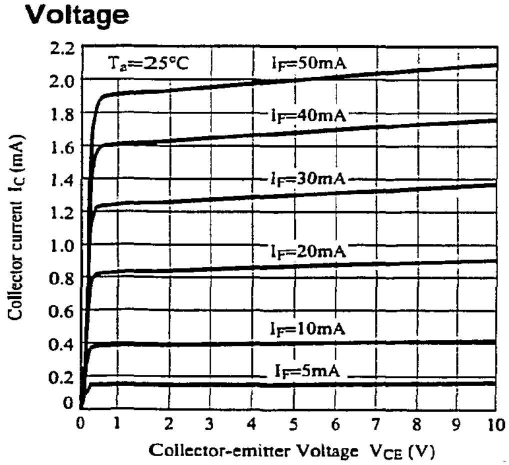


Fig.6 Relative Collector Current vs. Ambient Temperature

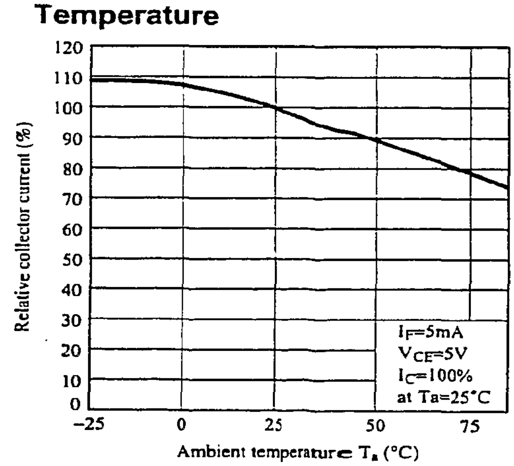


Fig.7 Collector-emitter Saturation Voltage vs. Ambient Temperature

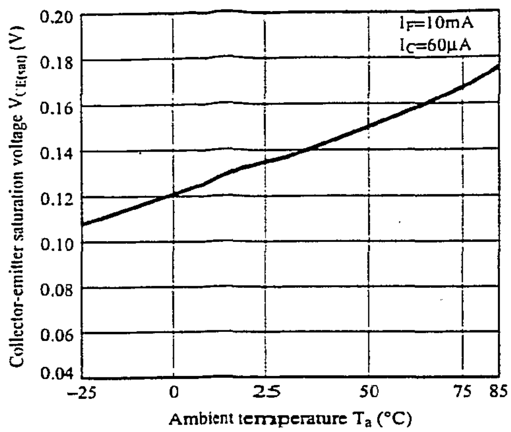


Fig.8 Response Time vs. Load Resistance

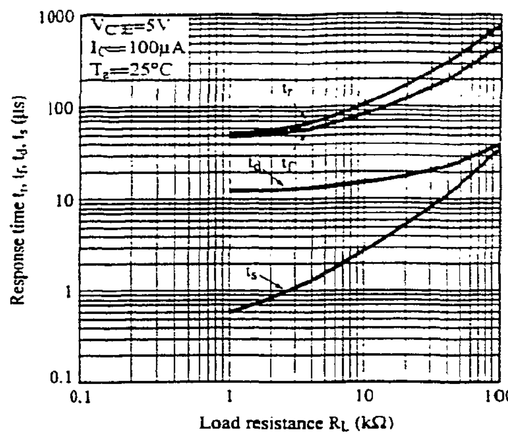


Fig.9 Collector Dark Current vs. Ambient Temperature

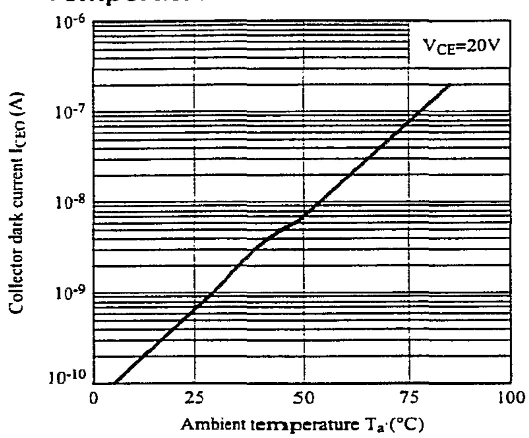
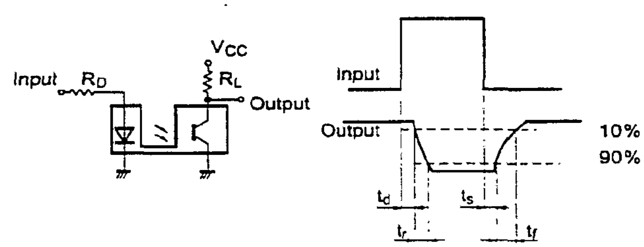


Fig.10 Test Circuit for Response Time



NOTICE

- The circuit application examples in this publication are provided to explain representative applications of SHARP devices and are not intended to guarantee any circuit design or license any intellectual property rights. SHARP takes no responsibility for any problems related to any intellectual property right of a third party resulting from the use of SHARP's devices.
- Contact SHARP in order to obtain the latest device specification sheets before using any SHARP device. SHARP reserves the right to make changes in the specifications, characteristics, data, materials, structure, and other contents described herein at any time without notice in order to improve design or reliability. Manufacturing locations are also subject to change without notice.
- Observe the following points when using any devices in this publication. SHARP takes no responsibility for damage caused by improper use of the devices which does not meet the conditions and absolute maximum ratings to be used specified in the relevant specification sheet nor meet the following conditions:

  (i) The devices in this publication are designed for use in general electronic equipment designs such as:
  — Personal computers
  — Office automation equipment
  — Telecommunication equipment [terminal]
  — Test and measurement equipment
  — Industrial control
  — Audio visual equipment
  — Consumer electronics

  (ii) Measures such as fail-safe function and redundant design should be taken to ensure reliability and safety when SHARP devices are used for or in connection with equipment that requires higher reliability such as:
  — Transportation control and safety equipment (i.e., aircraft, trains, automobiles, etc.)
  — Traffic signals
  — Gas leakage sensor breakers
  — Alarm equipment
  — Various safety devices, etc.

  (iii) SHARP devices shall not be used for or in connection with equipment that requires an extremely high level of reliability and safety such as:
  — Space applications
  — Telecommunication equipment [trunk lines]
  — Nuclear power control equipment
  — Medical and other life support equipment (e.g., scuba).
- Contact a SHARP representative in advance when intending to use SHARP devices for any "specific" applications other than those recommended by SHARP or when it is unclear which category mentioned above controls the intended use.
- If the SHARP devices listed in this publication fall within the scope of strategic products described in the Foreign Exchange and Foreign Trade Control Law of Japan, it is necessary to obtain approval to export such SHARP devices.
-
- Contact and consult with a SHARP representative if there are any questions about the contents of this publication.

WHAT IS CLAIMED IS:

1. A wearable electronic display unit for displaying an image in two modes, one mode where the primary viewer is a person who is wearing the display unit, and a second mode where the primary viewer is another person locating within reading distance of the person wearing the display unit, comprising:

a visible display unit adapted to be worn by a user, the display unit having a display capable of displaying an image;

a sensor that detects whether the display is oriented substantially in one vertical orientation or substantially in the opposite vertical orientation, and providing an electronic signal to indicate the vertical orientation;

whereby, in response to the signal from the sensor indicating that the display is oriented substantially in the one vertical orientation, the display orients the displayed image in a first vertical orientation, and in response to a signal from the sensor that the display is oriented in the opposite vertical orientation, the display orients the displayed image in a second, opposite vertical orientation.

2. A wearable electronic display unit for displaying an image in two modes, one mode where the primary viewer is a person who is wearing the display unit, and a second mode where the primary viewer is another person locating within reading distance of the person wearing the display unit, comprising:

a display unit having a visible display adapted to be worn by a user, the display being capable of displaying an image; and

a sensor that detects whether the display is oriented substantially in one vertical orientation or substantially in the opposite vertical orientation and providing an electronic signal to indicate the vertical orientation;

whereby, in response to a signal from the sensor indicating that the display is oriented substantially in the one vertical orientation, the displayed image is displayed in a manner adapted for viewing by the wearer, and in response to a signal from the sensor that the display is oriented in the opposite vertical orientation, the displayed image is displayed in a mode adapted for viewing by the other person.

3. The wearable electronic display unit of claim 2 wherein the displayed image is larger when the displayed image is displayed in the manner adapted for

viewing by the other person than when the displayed image is displayed in the manner adapted for viewing by the wearer.

4. The wearable electronic display unit of claim 2 wherein the displayed image is displayed in one vertical orientation when it is displayed in the manner adapted for viewing by the other person, and in the opposite vertical orientation when it is displayed in the manner adapted for viewing by the wearer.

5. A wearable electronic display unit for displaying graphics and text images and for communicating with other similar wearable displays, comprising:

a display unit having a visible, graphical display adapted to be worn by a user, the visible display being capable of displaying text and graphical images; and

a short range, substantially unidirectional electronic communication channel having a data transmitting and receiving interface incorporated in the display unit and located in a location on the display unit so that, when the display unit is worn by a wearer, the interface faces in a direction of the substantially unidirectional communication so as to make electronic communication possible with another person who also is wearing a similar display unit, whereby data can be exchanged between respective display units worn by two wearers through the interfaces on the respective display units.

6. The wearable electronic display unit of claim 5 wherein the electronic communication channel transmits and receives an infrared beam.

7. A wearable electronic display unit for displaying an image and for communicating with other similar wearable displays, comprising:

a display unit having a visible display adapted to be worn by a user, the visible display being capable of displaying an image;

a first short range electronic communication channel having a data transmitting and receiving interface incorporated in the display unit so as to make electronic communication possible with another person who also is wearing a similar display unit, whereby data can be exchanged between respective display units worn by two wearers through the interface on the respective display units; and

a second longer range electronic communication channel incorporated in the display unit and using a different type data transmission system from the first electronic communication channel.

8. The wearable electronic display unit of claim 7 wherein the first communication channel transmits and receives using an infrared beam.

9. The wearable electronic display unit of claim 7 wherein the second communication channel transmits and receives using RFID.

10. The wearable electronic display unit of claim 7 wherein the first communication channel transmits and receives using an infrared beam and the second communication channel transmits and receives using RFID.

11. The wearable electronic display unit of claim 7 wherein the second communication channel is capable of receiving data broadcast to a plurality of display units.

12. A wearable electronic display unit for displaying an image and for communicating with other similar wearable displays, comprising:

a display unit having a visible display adapted to be worn by a user, the visible display being capable of displaying an image;

an electronic communication channel having a data transmitting and receiving interface incorporated in the display unit and located on the display unit so that, when the display unit is worn by a wearer, the interface faces in a direction so as to make electronic communication possible with another person who also is wearing a similar display unit, whereby data can be exchanged between respective display units worn by two wearers through the interface on the respective display units; and

a timer contained in the display unit that provides time information to the electronic communication channel.

13. The wearable electronic display unit of claim 7 wherein the second communication channel is adapted to selectively receive a data broadcast to a plurality of display units.

14. The wearable electronic display unit of claim 13 further comprising a data detecting device that can determine if the data broadcast includes data intended for the wearer of the display unit.

15. The wearable electronic display unit of claim 5 further comprising a manual user interface incorporated in the display unit, allowing the wearer to enter data manually into the unit.

16. The wearable electronic display unit of claim 15 wherein the manual user interface includes buttons for scroll up, scroll down and select.

17. The wearable electronic display unit of claim 5 further including a signal generator adapted to communicate to the wearer that his or her attention is needed.

18. The wearable electronic display unit of claim 17 wherein the signal generator is a light generator.

19. The wearable electronic display unit of claim 18 wherein the light generator is an LED.

20. The wearable electronic display unit of claim 17 wherein the signal generator is a sound generator.

21. The wearable electronic display unit of claim 5 wherein the display unit is adapted to be worn on a lanyard around the wearer's neck.

22. The wearable electronic display unit of claim 5 wherein the display unit is adapted to be worn clipped to the wearer.

23. The wearable electronic display unit of claim 5 wherein the display is a back lighted LCD display.

24. The wearable electronic display unit of claim 23 wherein the backlight is timed to go off automatically after a predetermined time interval.

25. The wearable electronic display unit of claim 24 wherein the backlight is automatically turned on when a display unit worn by one person comes with a predetermined range of another display unit worn by another person.

26. The wearable electronic display unit of claim 15 wherein the manual interface includes a button that, when pressed, sends predetermined data to another display unit worn by another person.

27. The wearable electronic display unit of claim 12 wherein the display unit can communicate data that is time-related.

28. The wearable electronic display unit of claim 12 wherein the display unit can change functionality based upon a predetermined time elapse.

29. The wearable electronic display unit of claim 12 wherein the display unit can change receive or transmit predetermined information based upon an elapse of a predetermined amount of time.

30. The wearable electronic display unit of claim 7 wherein the second communication channel can be used to program the display unit.

31. The wearable electronic display unit of claim 7 wherein the second communication channel can be used to provide information from a plurality of display units.

32. The wearable electronic display unit of claim 5 further comprising a receiver for receiving GPS signals.

33. A method of communicating face-to-face, each display unit having a graphical display and two-way electronic communication capability, the display unit of a second wearer being worn on his or her person in a manner visible to a first wearer, comprising:

passing a first packet of information electronically from the display unit of the first wearer to the display unit of the second wearer, the information including personal information about the first wearer; and

displaying text information on the display unit of the second wearer that is based upon a comparison between the first packet of information and a second packet of information contained within the display unit of the second wearer, the second packet of information including personal information about the second wearer, whereby the displayed text information on the display unit of the second wearer is visible to the first wearer.

34. The method of claim 33 further characterized by the displaying information step being carried out in response to the receipt by the display unit of the second wearer of the first packet of information.

35. The method of claim 33 further characterized by each display unit being worn on the person of the wearer in a manner to be visible to the weárer of the other display unit.

36. The method of claim 33 further characterized by the step by the first wearer taking an action based upon the displayed information on the display unit of the second wearer.

37. The method of claim 36 further characterized by the action being assisted by the second packet of information.

38. The method of claim 36 further characterized by the action being an attempt to find a person.

39. The method of claim 37 further characterized by the action being an attempt to find a person.

40. The method of claim 33 further characterized by the second packet of information being information related to the second wearer.

41. The method of claim 33 further characterized by the second packet of information being information related to a third person who is not the first or second wearer.

42. The method of claim 33 further characterized by the first packet of information being information related to the first wearer.

43. The method of claim 33 further characterized by the first packet of information being information related to a third person who is not the first or second wearer.

44. The method of claim 33 further characterized by the second packet of information being information being time-related.

45. The method of claim 33 further characterized by the second packet of information being information related to a third person who is not the first or second wearer and being time-related.

46. The method of claim 45 further characterized by the second packet of information being information related to a time that has elapsed since the wearer of the second display unit has communicated with a third person who is not the first or second wearer.

47. The method of claim 33 further characterized by the second packet of information being information related to the location of a third person who is not the first or second wearer.

48. The method of claim 33 further characterized by the first and second packets of information both being information related to the same third person who is not the first or second wearer.

49. The method of claim 33 further characterized by one of the first and second packets of information being information related to others with whom the wearer of the first or second display units, respectively, has electronically communicated with.

50. The method of claim 33 further characterized by both the first and second packets of information being information related to others with whom the wearer of the first or second display units, respectively, has electronically communicated with.

51. The method of claim 33 further characterized by one of the first and second packets of information being information related to the number of others with whom the wearer of the second or first display units, respectively, has electronically communicated with.

52. The method of claim 33 further characterized by both the first and second packets of information being information related to the number of others with whom the wearer of the first or second display units, respectively, has electronically communicated with.

53. A method of communicating face-to-face between wearers of respective electronic display units, each display unit having a text display, two-way electronic communication capability, and the capability of entering information into the display unit manually, the display unit of a second wearer being worn on his or her person in a manner visible to a first wearer, comprising:

passing electronically a first packet of information, that includes information entered manually into the display unit of the first wearer, from the display unit of the first wearer to the display unit of the second wearer; and

displaying text information on the display unit of the second wearer that includes information based upon the first packet of information in addition to a second packet of information contained within the display unit of the second wearer, whereby the displayed text information on the display unit of the second wearer is visible to the first wearer.

54. The method of claim 53 further characterized by the second packet of information also including information entered manually into the display unit of the second wearer.

55. The method of claim 54 further characterized by the text information displayed on the display unit of the second wearer being based upon the information entered manually into the display units of the first and second wearers.

56. The method of claim 55 further characterized by the text information displayed on the display unit of the second wearer being based upon a comparison of the information entered manually into the display unit of the first wearer with the information entered manually into the display unit of the second wearer.

57. A method of communicating between a text display located in a fixed position and a wearer of an electronic display unit, the display unit having a text display and two-way electronic communication capability, the display unit being worn by the wearer in a manner to be able to communicate electronically with the text display located in a fixed position, comprising:

passing a first packet of information electronically from the display unit of the wearer to the text display located in a fixed position; and

displaying text information on the text display located in a fixed position that includes information based upon the first packet of information in addition to a second packet of information contained within the text display located in a fixed position, whereby the displayed text information on the text display located in a fixed position is visible to the first wearer.

58. A method of communicating face-to-face, at gatherings between wearers of respective electronic display units, each display unit having a text display and two-way electronic communication capability, the display unit of a second wearer being worn on his or her person in a manner visible to a first wearer, comprising:

passing a first packet of information electronically from the display unit of the first wearer to the display unit of the second wearer, the information including personal information about the wearer that includes information relating to personal activities of the first wearer at the gathering; and

displaying text information on the display unit of the second wearer that is based upon the personal activities of the first wearer contained in the first packet of information, and a second packet of information contained within the display unit of the second wearer, the second packet of information including personal information about the second wearer, whereby the displayed text information on the display unit of the second wearer is visible to the first wearer.

59. The method of claim 58 further characterized by the second packet of information including information relating to personal activities of the second wearer at the gathering.

60. The method of claim 7 wherein the second communication system is a radio communication system.

61. The wearable electronic display unit of claim 17 wherein the signal generator causes a vibration perceptible by the wearer.

62. A method of communicating face-to-face using two display units, the display unit of a second wearer being worn on his or her person in a manner visible to a first wearer, comprising:

passing a first packet of information electronically from the display unit of the first wearer to the display unit of the second wearer, the information including data pertaining to the social network of the first wearer; and

displaying text information on the display unit of the second wearer that is based upon a comparison between the first packet of information and a second packet

of information contained within the display unit of the second wearer, the second packet of information containing social network information pertaining to the second wearer, whereby the displayed text information on the display unit of the second wearer is visible to the first wearer, the text information expressing commonalities between the social networks of the two wearers.

63. The method of claim 62 further characterized by the displaying information step being carried out in response to the receipt by the display unit of the second wearer of the first packet of information.

64. The method of claim 62 further characterized by each display unit being worn on the person of the wearer in a manner to be visible to the wearer of the other display unit.

65. The method of claim 62 further characterized by the step by the first wearer taking an action based upon the displayed information on the display unit of the second wearer.

66. The method of claim 65 further characterized by the action being assisted by the second packet of information.

67. The method of claim 66 further characterized by the action being an attempt to find a person.

68. The method of claim 62 further characterized by the second packet of information being information related to the second wearer.

69. The method of claim 62 further characterized by the second packet of information being information related to a third person who is not the first or second wearer.

70. The method of claim 62 further characterized by the first packet of information being information related to the first wearer.

71. The method of claim 62 further characterized by the first packet of information being information related to a third person who is not the first or second wearer.

72. The method of claim 62 further characterized by the second packet of information being information being time-related.

73. The method of claim 62 further characterized by the second packet of information being information related to a third person who is not the first or second wearer and being time-related.

74. The method of claim 73 further characterized by the second packet of information being information related to a time that has elapsed since the wearer of the second display unit has communicated with a third person who is not the first or second wearer.

75. The method of claim 62 further characterized by the second packet of information being information related to the location of a third person who is not the first or second wearer.

76. The method of claim 62 further characterized by the first and second packets of information both being information related to the same third person who is not the first or second wearer.

77. The method of claim 62 further characterized by one of the first and second packets of information being information related to others with whom the wearer of the first or second display units, respectively, has electronically communicated with.

78. The method of claim 62 further characterized by both the first and second packets of information being information related to others with whom the wearer of the first or second display units, respectively, has electronically communicated with.

79. The method of claim 62 further characterized by one of the first and second packets of information being information related to the number of others with whom the wearer of the second or first display units, respectively, has electronically communicated with.

80. The method of claim 62 further characterized by both the first and second packets of information being information related to the number of others with whom the wearer of the first or second display units, respectively, has electronically communicated with.

81. A method of communicating face-to-face, at gatherings between wearers of respective electronic display units, each display unit having a text display and two-way electronic communication capability, the display unit of a second wearer being worn on his or her person in a manner visible to a first wearer, comprising:

passing a first packet of information containing relationship information pertaining to the wearer of the display unit to the display unit of the second wearer, the first packet of information including personal information about the wearer that includes information relating to people known to the first wearer; and

displaying text information on the display unit of the second wearer that is based upon the relationship information of the first wearer contained in the first packet of information, and a second packet of information contained within the display unit of the second wearer that contains information relating to people known to the second wearer, whereby the displayed text information on the display unit of the second wearer is visible to the first wearer and displays information relating to people know in common by the two wearers.

82. A wearable electronic display unit for displaying images and for communicating with other similar wearable displays, comprising:

a first display unit having a visible display adapted to be worn by a first person, the visible display being capable of displaying text and graphical images, the first display unit containing information relating to the first person's social network database and the first unit having the capability to compare data from social network databases; and

a short range, substantially unidirectional electronic communication channel having a data transmitting and receiving interface incorporated in the first display unit and located in a location on the first display unit so that, when the first display unit is worn by a wearer, the interface faces in a direction of the substantially unidirectional communication so as to make electronic communication possible with a second person who also is wearing a second display unit, the second display unit containing information relating to the second person's social network database and also having the capability to compare data from social network databases, whereby data relating to each person's social network database can be exchanged between respective display units worn by the two persons through the interfaces on the respective display units, and the social network databases of the two persons may be compared in one of the display units and the results displayed on one of the display units.

83. The wearable electronic display unit of claim 82 wherein the electronic communication channel transmits and receives an infrared beam.

84. The electronic display unit of claim 82 further including a sensor that detects whether the display is oriented substantially in one vertical orientation or substantially in the opposite vertical orientation, and providing an electronic signal to indicate the vertical orientation.

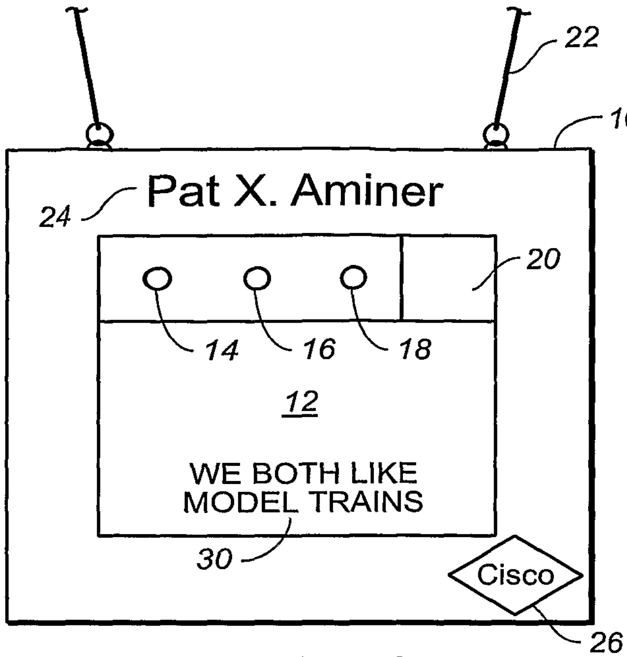


FIG._1

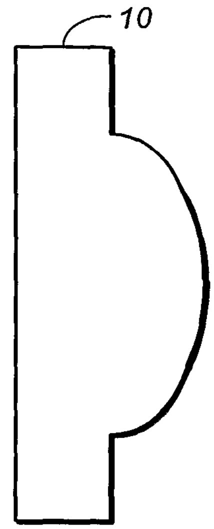


FIG._2

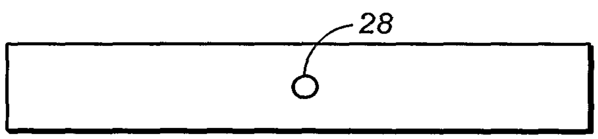


FIG._3

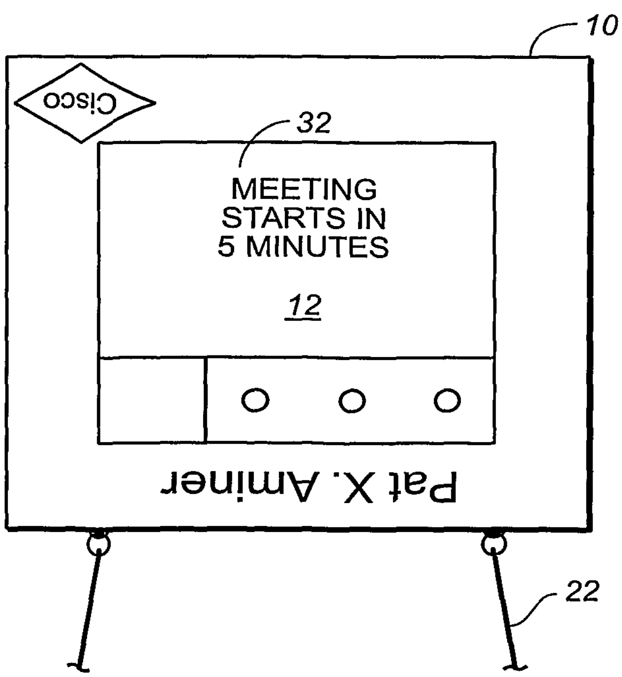


FIG._4

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 October 2004 (07.10.2004)

PCT

(10) International Publication Number
WO 2004/086288 A3

(51) International Patent Classification[7]**:** **G09G 3/00**, 5/00

(21) International Application Number: PCT/US2004/008773

(22) International Filing Date: 22 March 2004 (22.03.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/396,064 24 March 2003 (24.03.2003) US
10/729,696 5 December 2003 (05.12.2003) US

(71) Applicant *(for all designated States except US)*: **NTAG INTERACTIVE CORPORATION** [US/US]; 311 Summer Street, 5th Floor, Boston, MA 02210 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **BOROVOY, Richard, D.** [US/US]; 221 Columbus Avenue #404, Boston, MA 02116 (US). **EBERSTADT, George, A.** [US/US]; 52 Riverside Drive #14A, New York, NY 10024 (US).

(74) Agent: BOROVOY, Roger, S.; Fish & Richardson P.C., P.O. Box 1022, Minneapolis, MN 55440-1022 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

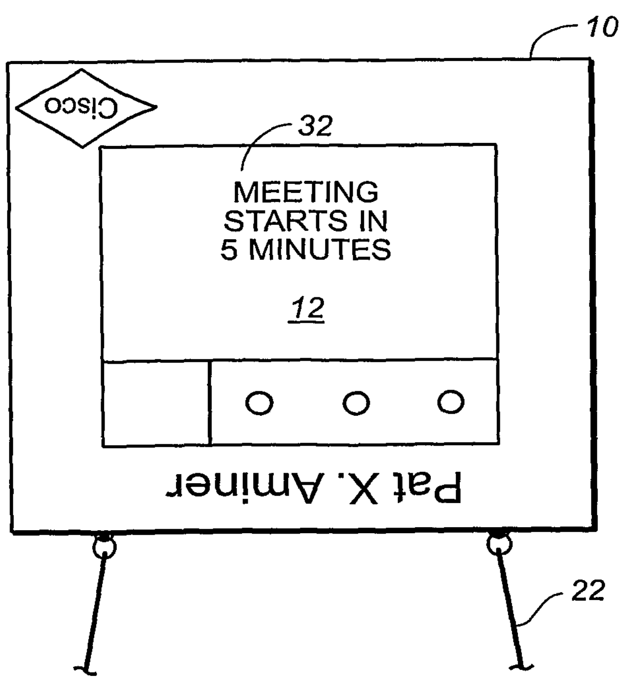
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(88) Date of publication of the international search report: 16 February 2006

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: APPARATUS AND METHOD FOR ENHANCING FACE-TO-FACE COMMUNICATION



(57) Abstract: A wearable electronic tag (10) for displaying graphics (12) and text images (30) and for communicating with other similar tags (10). Each tag (10) includes a visible, graphical display (12) adapted to be worn by a user. The tag (10) also includes a short range, substantially unidirectional electronic communication channel, such as an infrared transmitter-receiver, located on the display unit (10) so that, when the display unit (10) is worn, the interface (20) faces in a direction of the directed communication with another person who also is wearing a similar tag (10). This arrangement makes possible automatic data exchange and comparison of the interchanged data and display of the results of the comparison on the tags (10) worn by the two wearers. The tags (10) also have a longer range wireless communication system to receive and transmit data.

WO 2004/086288 A3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US04/08773

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G09G 3/00, 5/00
US CL : 345/8, 340/572.1

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 345/7-9, 340/572.1,691.6

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X, T	US 2005/0174302 A1 (ISHII) 11 August 2005, figures 7 and 20, pargraphs [0083] and [0184]-[0188].	1-4
A, T	US 6,842,121 B1 (TUTTLE) 11 January 2005, figures 2-4, column 4, lines 28 through columns 5-8.	5-84
X, P	US 2003/0193399 A1 (HUM ET AL.) 16 October 2003, figures 4A-4C, paragraphs [0044]-[0048].	5-84
X, T	US 2004/0201479 A1 (GARBER ET AL.) 14 October 2004, figures 3-8 and 13, paragraphs [0036]-[0062].	5-84

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 October 2005 (20.10.2005)	02 DEC 2005

Name and mailing address of the ISA/US
Mail Stop PCT, Attn: ISA/US
Commissioner of Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
Facsimile No. (703) 305-3230

Authorized officer
Kevin M. Nguyen
Telephone No. 571-272-7697

INTERNATIONAL SEARCH REPORT

PCT/US04/08773

Continuation of B. FIELDS SEARCHED Item 3:
EAST, database, US, US-PGPUB, EPO, JPO, DERWANT, IBM_TDB; search term: [(wear$4 near4 display) or (head adj (up or mount$3) adj display)] and [(radio adj frequency adj identification adj (system or communication or device)) or RFID] and (display$3 near (direction or orientation or rotat$4 or portrait or lanscape or horizontal or vertical))